2007 Joint Service Power Expo

"Power & Energy Independence for Warfighters"

24 – 26 April 2007

San Diego, CA

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TUESDAY, 24 APRIL 2007

OIF – Stories From the Field – Lessons Learned

WEDNESDAY, 25 APRIL 2007

Workshop Battery Technical Manuals and Milspecs, *Ms Susan Waggoner*
- Solar Power Adapters and Deployable and Renewable Alternative Energy Module, *Major David Morris*
- Tactical Power Systems, *Mr. Tom Lederle*
- Self-Generated Field Power Sources, *Mr. Albert Hartman*

THURSDAY, 26 APRIL 2007

- USMC Family of Environmental Control Equipment, *Major David C. Morris*
- Integrated Trailer-ECU-Generator (ITEG), *Major David C. Morris*
- Solving power supply obsolescence, reliability, and power density issues by advances in power electronics technology, *Mr. Richard Sidley*
- Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications, *Shailesh Shah*
- Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications, *Mr. Andy Wallace*
    - Video *Customer Broadcast*
    - Video *Customer UAV*
    - Video *Customer UGV*
- Data Systems for Enhanced Power and Energy Management, *Mr. John Adams*
- Back up Slides - Data Systems for Enhanced Power and Energy Management, Part 2 *Mr. John Adams*
- Portable Power Sources: One Size Fits None – Protonex Technology Corp, *Mr. Phil Robinson*
- Solid Oxide Fuel Cell Power Systems for Small UAV's, *Mr. Timothy LaBreche*
    - Video *UAV Fuel Cell Flight with Timer*
    - Video *11.5 Hr Ground Test with Time*r
    - Video *BOP Buner UAV*
    - Video *Short Crash Loop*
- Portable, JP-8 fueled battery charger for remote operation and portable solid oxide fuel cell systems, *Ms. Christine Martin*

Monday, April 23, 2007

1:00 p.m. - 5:00 p.m.	**Exhibitor Move-in**

Tuesday, April 24, 2007

7:30 a.m. - 8:30 a.m.	**Continental Breakfast**	
8:30:00 a.m. - 9:30 a.m.	**General Session**	
	Admin Remarks	
	Color Guard	
	Welcoming Address	
	Keynote Speaker	**Major General Stephen T. Johnson**
9:30 a.m. - 5:00 p.m.	**Exhibit Hall Open**	
9:30 a.m. - 10:00 a.m.	**BREAK in Exhibit Hall**	
10:00 a.m. - 11:30 a.m.	**OIF - Stories from the Field - Lessons Learned**	
	LtCol K. Jansen	**A Few OIF Power Observations**
	Ken Zemach	**Battlefield Power for the Warfighter Lessons for the Development Community**
	GySgt R.L. Gardner	**9th COMM BN ENGINEERS OIF LESSONS LEARNED**
	GySgt G.V. Yanez	**OIF 5-7 Commercial Power Generators**
11:30 a.m. - 1:30 p.m.	**LUNCH**	
1:30 p.m. - 3:00 p.m.	**Session 1 - Chair: Joanne Martin joanne.martin@usmc.mil**	**Session 2 - Chair: Don Brockel Donald.Brockel@us.army.mil**
	Doing Business with the Government - Yvonne Hicks & Shekela Hutchinson	**Determining the Right Type and Quantity of a Power Source - US Army CERDEC/LRC, Don Brockel (#4931)**
	Doing Business with the Marine Corps - Shekela Hutchinson	**Future of US Navy Electromotive Power Logistics - NAVAIR, LCDR Davis Spurlock (#4841)**
	Marine Corps Systems Command Purchasing & Evaluation of Power Items - Michael Gallagher	**Planning and Decision Support for Enhanced Power and Energy Management - MTS Technologies, Inc., Stephen Sullivan (#4823)**
3:00 p.m. - 3:45 p.m.	**BREAK in Exhibit Hall**	
3:45 p.m. - 5:15 p.m.	**Session 3 - Chair: Mike Brundage Michael.Brundage1@us.army.mil**	**Session 4 - Chair: Bob McKenzie robert.h.mckenzie@usmc.mil**
	Future Trends and Thrust for Army Manportable Power Sources - CERDEC, Mike Brundage (#4930)	**Marine Corps Mobile Electric Power Distribution System Replacement - USMC, MSgt Fred McCue (#4649)**
	Advancements in Navy and USMC Power Systems - NSWC Carderock, Justin Govar (#4902)	**The Case for Smart/Safe Power Management and Distribution for the Military - Custom Manufacturing & Engineering (CME), Rick Silva (#4835 & 4839)**
	DoD Battery Technical Working Group - US Army roadmaps and databases CERDEC, Marc Gietter (#4929)	**Fuel reduction solutions for deployment of mobile electric power systems - Oerlikon Contraves, Philippe Bisaillon Eng. MEM (#4805)**
6:00 p.m. - 8:00 p.m.	**Conference Reception in Exhibit Hall**	

Wednesday, April 25, 2007

Time			
7:00 a.m. - 5:30 p.m.	Exhibit Hall Open		
7:00 a.m. - 8:00 a.m.	Continental Breakfast in Exhibit Hall		
8:00 a.m. - 9:30 a.m.	Session 5 - Chair: Maj Daniels regina.daniels@us.army.mil Mobile Electric Power for Today and Tomorrow - DoD Project Manager Mobile Electric Power, Paul Richard (#4829)	Session 6 - Chair: Julie Banner julie.banner@navy.mil Ultralast Chinese Li/FeS2 Cells - David Hale Associates, Inc., Robert Byrnes Sr. (#4860) High Voltage Systems: Do's and Don'ts - Naval Surface Warfare Center Crane, Susan Waggoner (#4918) Large-sized Li-ion battery module for hybrid powered energy systems - GS Yuasa Corp., Koichi Nishiyama (#4690)	Session 7 - Chair: Mike Bissonnette mbissonnette@mkisystems.com MILITARY TRAINING Communications power sources & vehicle battery maintenance
9:30 a.m. - 10:15 a.m.	BREAK in Exhibit Hall		
10:15 a.m. - 11:45 a.m.	Session 8 - Chair: Maj Daniels regina.daniels@us.army.mil Mobile Electric Power Lessons Learned in the Global War on Terror - USMC, Robert McKenzie III (#4647) Case Study - Reducing Premature Failure of Parts with Interactive Virtual Training for Generator Operators - NGRAIN Corp., Erik Kaas (#4840) Lightweight 2-kW Generator with Electric Start and Voltage Regulation - Mainstream Engineering Corp., Gregory Cole (#4884)	Session 9 - Chair: Don Brockel Donald.Brockel@us.army.mil Servicing Hawker Vehicle Batteries with Standard Battery Charging and Test Equipment - US Army, TARDEC, Fred Krestik (#4672) Battery Maintenance and Management - Pulsetech Products Corp., Mark Abelson (#4818) Hybrid Li-ion/VRLA Battery for Silent Watch - Modular Energy Devices, Stephen Eaves (#4668)	Session 10 - John O'Donnell john.h.odonnell@usmc.mil Testing of COTS/NDI products (Joint presentation) (#4882)
11:45 a.m. - 1:45 p.m.	LUNCH Speaker - Hon. Philip E. Coyle III		
1:45 p.m. - 3:15 p.m.	Session 11 - Chair: Mike Gallagher michael.a.gallagher@usmc.mil DOD Efforts in On-Board Vehicle Power (Joint presentation) (#4639)	Session 12 - Chair: Marc Gietter marc.d.gietter@us.army.mil Research and Development, GEN4 Zinc Air Battery Technology - Electric Fuel Battery Corp., Darrel Morris (#4830) Flexible Hybrid Power Architecture and Evaluation of Multiple Sources Under Load - US Air Force Research Labs, Lt Joshua Johnson (#4837) Power Surety for the Long War - US Army, Rapid Equipping Force Power Surety Branch, Daniel Nolan III (#4662)	Session 13 - Chair: CWO5 Good pamela.good@usmc.mil MILITARY TRAINING Generators & AUTODISE
3;15 p.m. - 4:00 p.m.	BREAK in Exhibit Hall		
4:00 p.m. - 5:30 p.m.	Session 14 - Chair: Mike Gallagher michael.a.gallagher@usmc.mil Oshkosh Truck's electric drive approach to mobile power platforms - Oshkosh Truck Corp., Nader Nasr (#4822) 30 kW On-Board Vehicle Power for the HMMWV - ePower LLC, William Henrickson (#4700)	Session 15 - Chair: Sue Waggoner susan.waggoner@navy.mil Workshop - Battery Documents Navy Aircraft and Army C/E - US Navy & US Army, Susan Waggoner & Pat Lyman (#4917)	Session 16 - Chair: Jonathan Hernandez jhernandez@fbiacademy.edu Solar Power Adapters and Deployable and Renewable Energy Alternative Module - Marine Corps Systems Comand, Maj David Morris, (#4673 & 4686) Need for Tactical Off-Grid Solar Power System - NEST Energy Systems, Tom Lederle (#4940)

		Self-Generated Field Power Sources - High Tide, Albert Hartman (#4807)

Thursday, April 26, 2007

7:00 a.m. - 12:00 p.m. — **Exhibit Hall Open**

7:00 a.m. - 8:00 a.m. — **Continental Breakfast in Exhibit Hall**

8:00 a.m. - 9:30 a.m.

Session 17 - Chair: Maj Daniels regina.daniels@us.army.mil	Session 18 - Chair: Jonathan Hernandez jhernandez@fbiacademy.edu
The Family of Environmental Control Equipment - Marine Corps Systems Command, MSgt Teresa Terry (#4689)	Moving Forward with Fuel Cells: Army CERDEC Development & Demonstration Progress - US Army, CERDEC, Elizabeth Bostic (#4684)
Integrated Trailer, Environmental Control Unit, and Generator (ITEG) - Marine Corps Systems Command, Maj David Morris (#4674)	XX25 Reformed Methanol Fuel Cell for Portable Power Applications - UltraCell Corp., Ian Kaye (#4755)
Solving power supply obsolescence, reliability, and power density issues by advances in power electronics technology. - Custom Manufacturing & Engineering, Richard Sidley (#4833)	Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications - Millennium Cell Inc., Shailesh Shah (#4877)

9:30 a.m. - 10:15 a.m. — **BREAK in Exhibit Hall**

10:15 a.m. - 12:00 p.m.

Session 19 - Chair: Sue Waggoner susan.waggoner@navy.mil	Session 20 - Chair: Jonathan Hernandez jhernandez@fbiacademy.edu
Data Systems for Enhanced Power and Energy Management - MTS Technologies, Inc., Zachary P. Hubbard (#4826)	Durability and Performance issues of PEM Fuel Cell Systems for Portable Applications - Hampton University, Dr. Amir Hoshang Chegini (#4685)
Powering the Mobile Warfighter: One Size Fits None - Protonex Technology Corp., Phil Robinson (#4832)	Solid Oxide Fuel Cell Power Systems for Small UAVs - Adaptive Materials, Inc., Brad Clawson (#4838)
The Next Level of Intelligent Power Management & Distribution - Energy Technologies, Inc., Tim Lowe (#4836)	Military 3 kW Jet-Fueled Tactical Fuel Cell Generator - IdaTech, LLC, Eric Simpkins (#4706)
	Portable, JP-8 fueled battery charger for remote operation and portable solid oxide fuel cell systems - Mesoscopic Devices, LLC, Christine Martin & Dr Jerry Martin (#4709 & 4710)

12:00 p.m. — **Conference Adjourns**

12:00 p.m. - 4:00 p.m. — **Exhibitor Move-out**

26 April AGENDA

- MCCDC Presentation - Bill Simons (45 minutes)
- TFSMS Presentation - Robin Roberts (5 minutes)
- GCSS presentation - MGySgt Smith (10 minutes)
- Trailer Presentation - John O'Donnell (15 minutes)
- Refrigeration systems update - Maj Morris (15 minutes)
- Comments / impressions from Expo (Joanne lead)
- Topics from the audience
- Last minute details for Friday I MEF conference
- Breakout sessions:
  - COMM Discussion/Meeting - Joanne Martin (lead)
  - Utilities Discussion/Meeting – CWO5 Good (lead)

Solid Oxide Fuel Cell Power Systems for Small UAVs

2007 Joint Service Power Expo
April 24-26 2007

Timothy LaBreche

Adaptive Materials, Inc.
4403 Concourse Drive, Suite C
Ann Arbor, MI 48108
734.302.7632

www.adaptivematerials.com

Outline

- About Adaptive Materials (AMI)
- AMI Technology & Systems
- Unmanned Aerial Vehicles Power Systems

About AMI

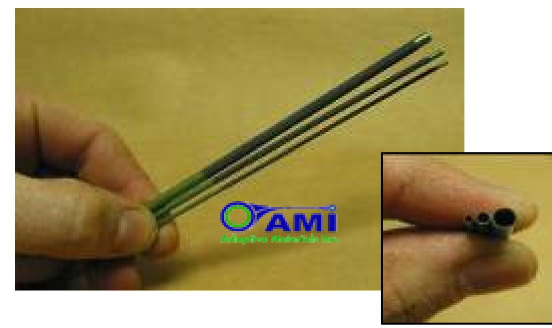
- Ann Arbor, Michigan
- Portable Solid Oxide Fuel Cells
- 25W, 50W and 150W Systems

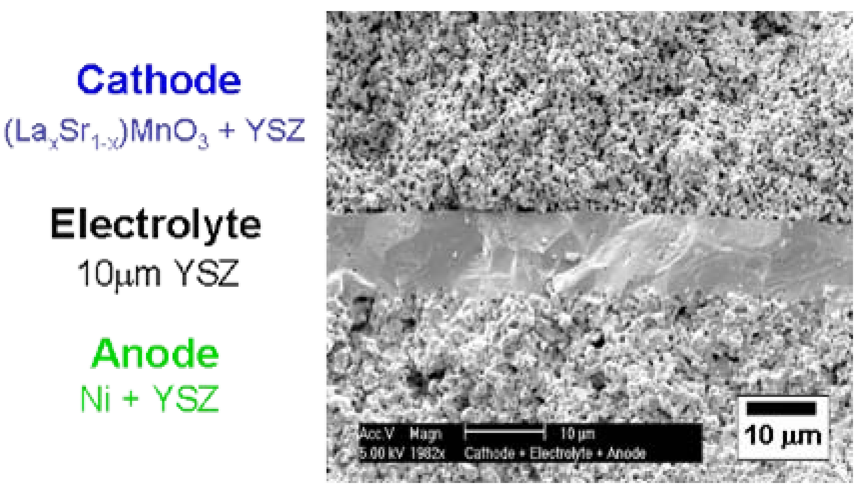
e50

Technology

- Technology originated with large scale power generation
- Low cost ceramic materials
- Real fuel - hydrocarbons

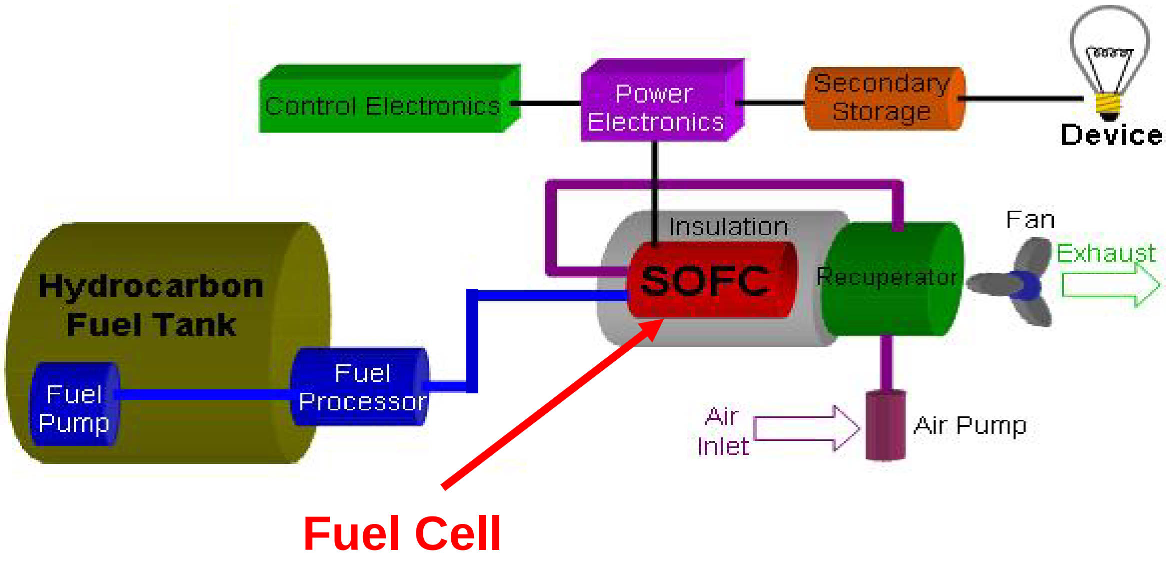
Micro-tubular Fuel Cells





Technology

- Cells coupled into Stack
- Balance of Plant



Technology

Pilot scale manufacturing facility

- Capacity 100,000 cells per year
- Six Sigma based process improvement

SOFC = Fuel Flexibility

Propane Fuel Tank
9,675 Whr/kg

Global Commodity

- **Maximum Portable Performance**
  - Highest energy density of any packaged fuel
- **100% Consumer Confidence**
  - DOT and UN certified tanks
    - Ground and air shipping
  - Global commodity
    - Existing supply chain and distribution
  - Low Cost
- **You can step outside this room and find fuel for the UAV power system within an hour.**

e50

- **50 Watt Continuous Power**
  - 12V
  - 100 Watt peak power

- **System Specifications**
  - Dry system weight, less than 2.25 kg
  - Temperature -20ºC to 50ºC
  - Relative Humidity 5% to 95%
  - 12,500 feet with 0% power degradation
  - Dust and rain to military specification
  - Rapid Start Up < 15 minutes
  - Exhaust temperature <55ºC
  - Multiple fuel compatible

e50

Supply Chain Partners
Parker Hannifin for BOP Assemblies

e50

50W System

Specifications	
Dry Weight	2.25kg
Volume	4.5
Net System Efficiency	17%

Specific Energy

3 Day Mission W-hr/kg	**775**
10 Day Mission W-hr/kg	**1200**

End of Life Testing

Goal = 300 Hours
Tested MTBF = 500 Hours

Rapid Start - Stop Testing

Goal = 100 cycles
Avg Cycles = 144 cycles

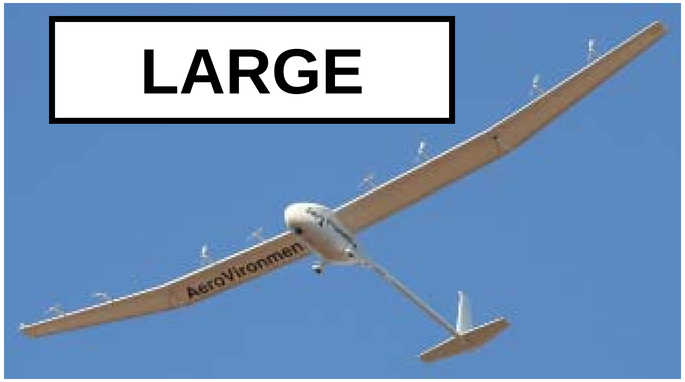
Why Fuel Cell Powered UAVs?

- Quieter than internal combustion engines
- Far more efficient than small fractional horsepower engines
- More range and endurance than batteries
  - Much higher Whr/Kg
- Electric power for payload

Hydrogen Fuel Cell Aircraft In All Sizes

SMALL

- Aerovironment / Lynntech
  - Hornet Micro Air Vehicle 2003
- NRL
  - 2005 - Spider Lion: 100 Watts: PEM : 2 meter span
- California State University, Los Angeles
  - 2006 – 500 Watts: PEM: 5.5 meter span
- Georgia Tech
  - 2006 – 500 Watts: PEM: 6.5 meter span
- Light Human Carrying Aircraft
  - UQM Technologies & BR&TE
- Aerovironment / NASA Dryden
  - Helios
  - HALE



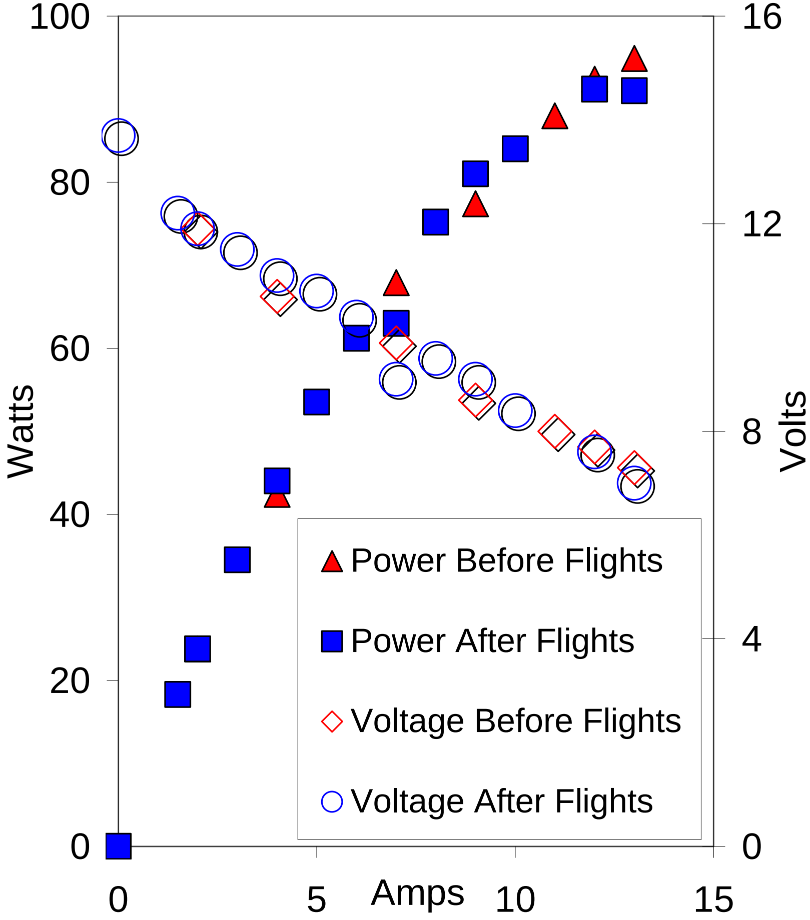
http://www.avinc.com/publish/2006/01/05/1092_ ______________GO_Aerial_View2.jpg

SOFC UAV Power Systems are Robust

February 2005

Early Test Flights - Video

Stack Performance Before & After Repetitive Crashes



Ceramic Not Always = Fragile

Gen One SOFC Powered UAVs

June 2006

UAV Specifications	
Gross UAV Take Off Weight	1.94 kg
SOFC System Dry Weight	0.9 kg
SOFC System Wet Weight	1.06 kg
Cruise Power	~60 Watts
SOFC Dry Specific Power	**72 W/kg**
Flight Specific Energy	**250 Whr/kg**

4 hour 19 minute Flight

- More than 4 hours aloft using a 60 Watt Solid Oxide Fuel Cell system weighing less than 1 kilogram.

Flight and Ground Test Results

Date	Event	Duration (Hrs)	Energy Density (W-hr/kg)
Feb 2005	Flight	0.25	-
Oct 2005	Flight	0.17	-
Jun 2006	Flight	1	60
Jun 2006	Flight	2.3	138
Jun 2006	Flight	4.3	250
Nov 2006	Autonomous Ground Test	11.5	680
Nov 2006	Autonomous Ground Test	8	443
Nov 2006	Autonomous Ground Test	8	440
Nov 2006	Autonomous Ground Test	8	414

Program Highlights

Generation I

250 Whr/kg

Generation II

660 Whr/kg

- Flight tests and bench top endurance runs to prove feasibility of SOFC UAV
- 4:19 flight represents a “world record” in fuel cell powered UAVs

Acknowledgements

- Department of Defense and other agencies
- The AMI team

Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications

Andy Wallace
Director of Technology Development

Jadoo Power Systems
181 Blue Ravine, Folsom, CA, 95630
apwallace@jadoopower.com

Who Is Jadoo Power

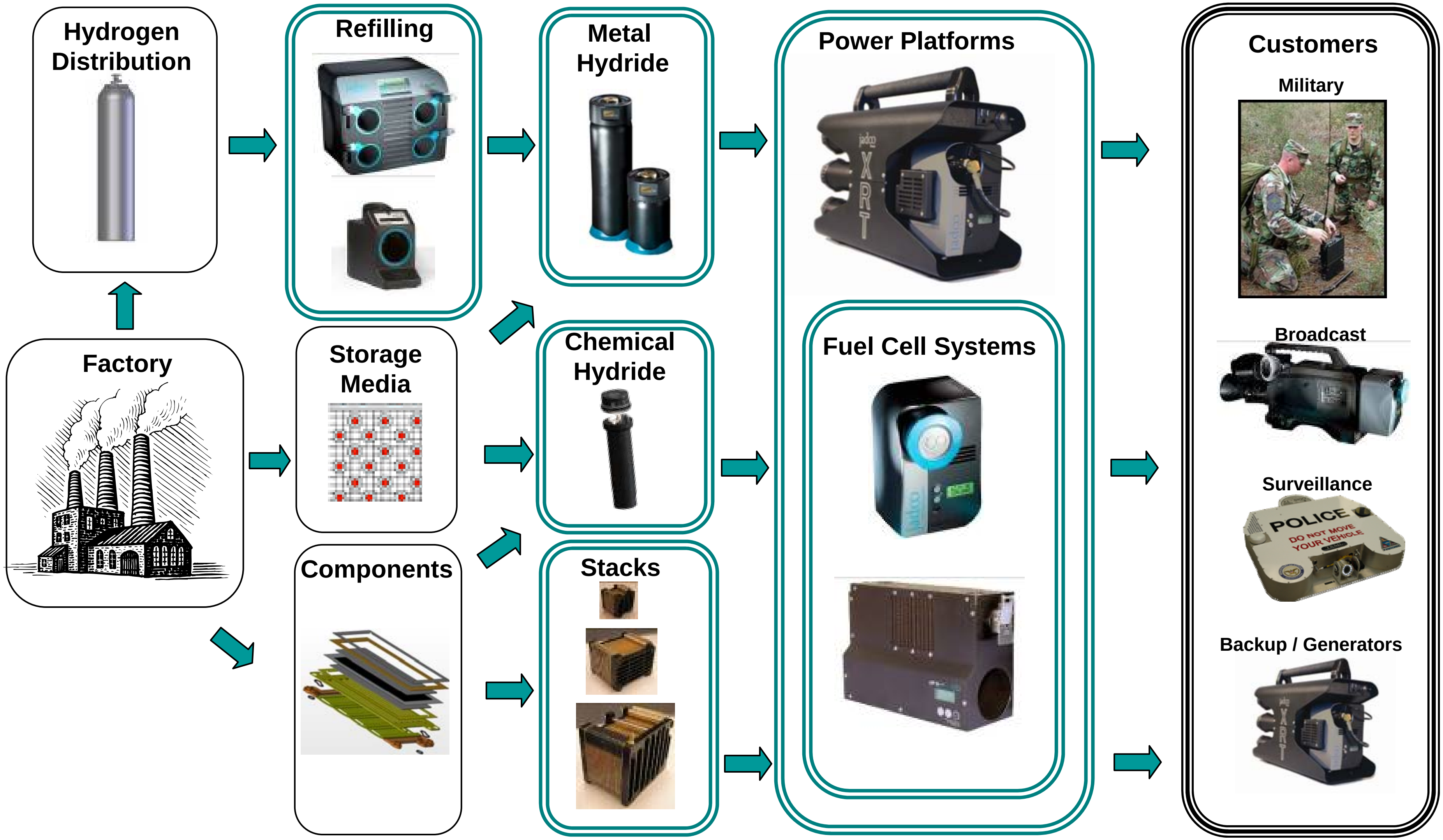
- **#1 Fuel Cell Systems Integrator**
  - Complete Portable Power Solutions Commercially Available
  - Market Focus: 20 to 5kW
  - 75,000 hours cumulative runtime over 100's of systems
- **Private Company**
  - Founded November 2001
  - Folsom CA
  - 32 Employees
- **Twenty Six Patent Applications**
- **Investors:**

Venrock Associates

MDV Mohr, Davidow Ventures

SBG Sinclair Ventures

Customers Buy Complete Solutions



Published Pricing

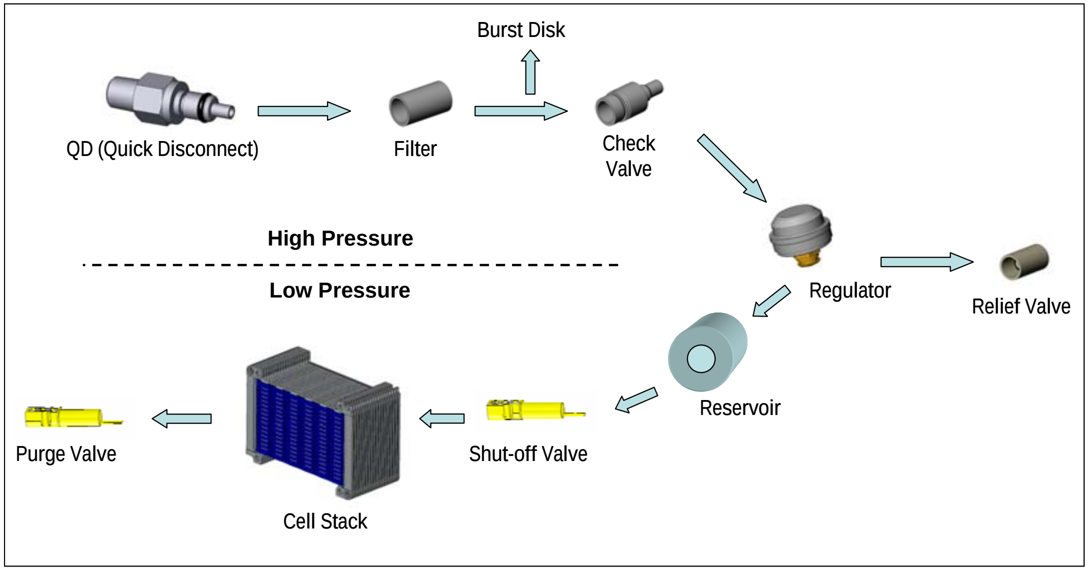
- Fuel Canister (N-Stor130 / N-Stor360) $449 - $849
- Fuel Cell Power Unit (N-Gen) (100W) $999
- Refill Stations (FillOne / FillPoint) $599 - $1,799
- Runtime Extension (XRT) $1,999
- Cables and Accessories $79

Available on website TODAY!

>>BUY NOW!

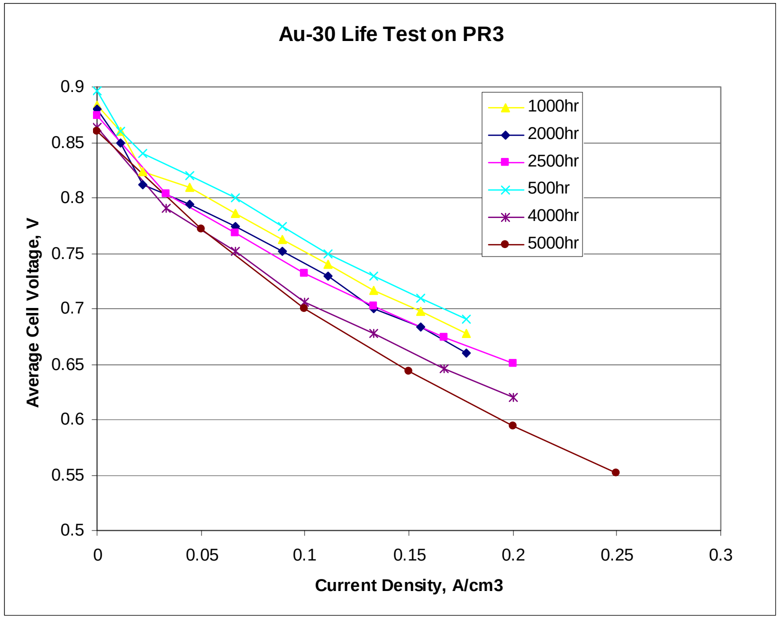
Jadoo Fuel Cell Architecture

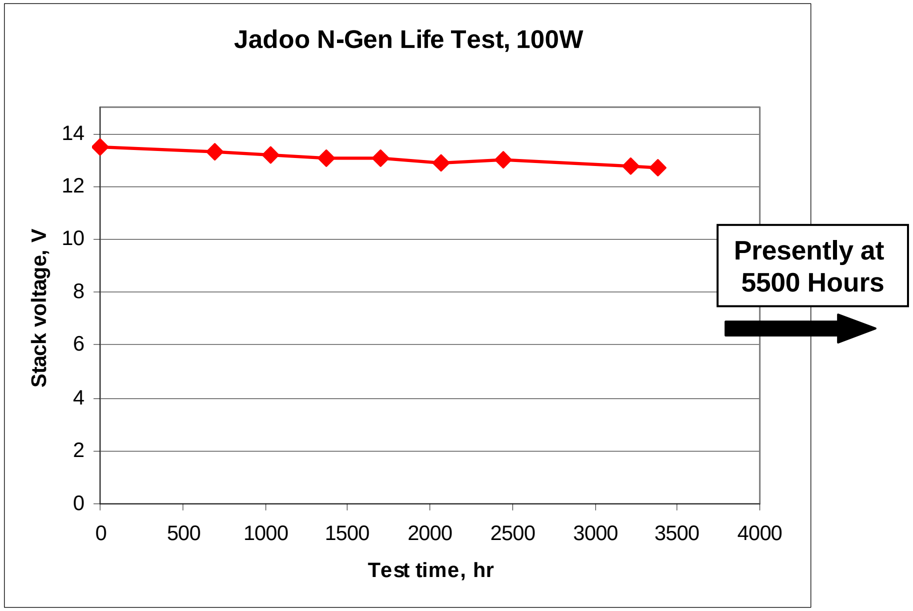
- **Approach: Dead-Ended Anode With Open Cathode**
- **Core Fuel Cell Components: Stack, Fan, Regulator**
- **Key Challenge: Stack Dry-out At High Temperatures**
  - Solution: Passive Self-humidification Structures



Jadoo Stack Performance and Design

- **>7,000 startup/shutdown cycles**
- **>5,000 hrs of life in continuous power tests.**
  - Voltage decay rate <10 uV/hr/cell.
- **>10,000 vacuum/pressure cycles**





The Hydrogen Economy of Portable Systems

	Metal Hydride	Sodium Borohydride	Ammonia Borane
Supplier/Partner	Ovonics	Millennium Cell	General Atomics
Energy (5lb / 2.27kg of fuel + packaging)	400 W-hr	>1360 W-hr	>2270 W-hr
Energy Density	150 W-hr/kg	>600 W-hr/kg	>1000 W-hr/kg
Availability	Now	2008	2009
Status	Production	Functional Prototypes	Laboratory Development
			

Standardized Interfaces Provides Customer Options

Metal hydride

Chemical hydride

Ammonia Borane

N Stor Interface

N Stor interface provides universal connectivity to multiple fuel options through standardized connection of power, data and fluids

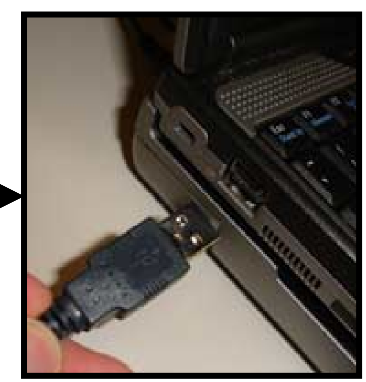
Analogous to USB interface provides universal connectivity to multiple wireless communications options through standardized connection of power and data

Blue tooth

3G Cellular Modem

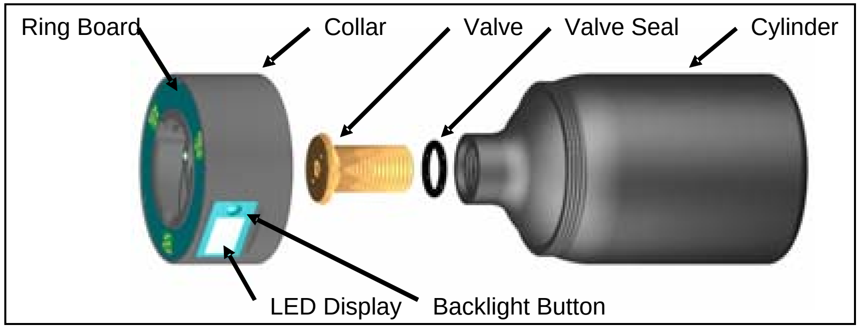
Wireless Adapter

USB Interface



Metal Hydride Canisters

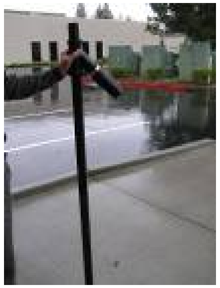
- **Unqiue Achievements**
  - Only state-of-fill solution for portable hydrogen/fuel storage
  - Only Department of Transportation air cargo exempt hydrogen canister
  - >10,000 Cycles
  - -55 to 150°F



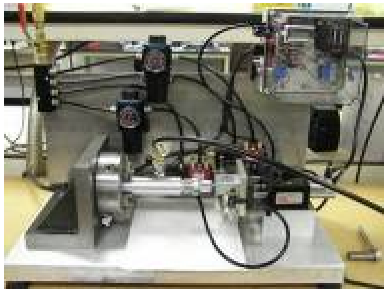
Ballistics

Thermal

Drop



Cycling



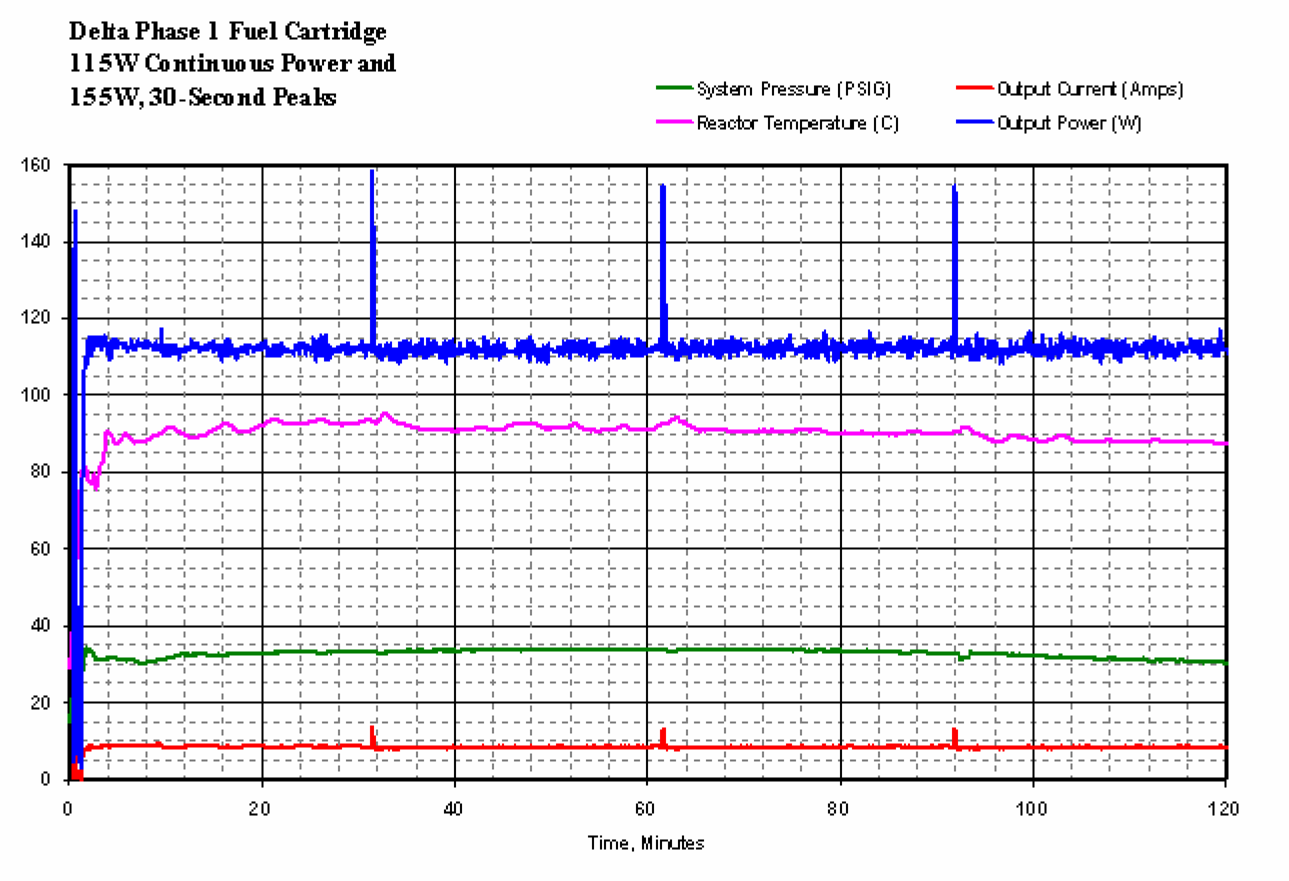
Bonfire

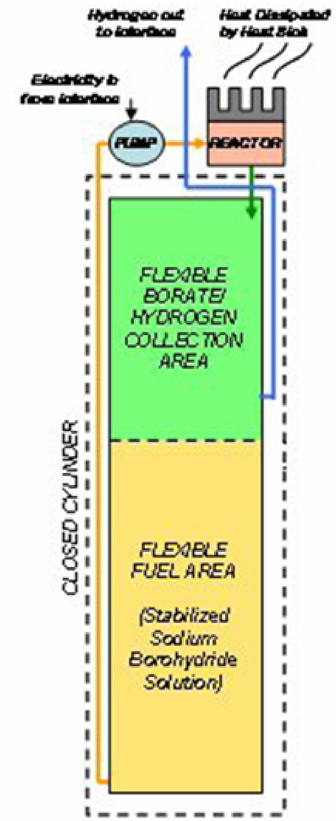
Sodium Borohydride Development Activities

- **Direct Metal Hydride Replacement**
  - Funded by Jadoo, Millennium Cell, and Kuchera Defense Systems
  - 100 W Continuous
  - >300 Whrs
  - >300 Whrs/kg
  - Commercial Evaluation Program 2008
- **Custom System for 300W Aeromedical Evacuation**
  - Funded by Air Force Research Lab
  - 300W Continuous
  - >3600 Whrs
  - >600 Whrs/kg
  - Demonstration 2007

Sodium Borohydride

- >100W Capability Demonstrated
- Orientation Independent
- Auto-Starting
- Full Power Available in ~15 Seconds



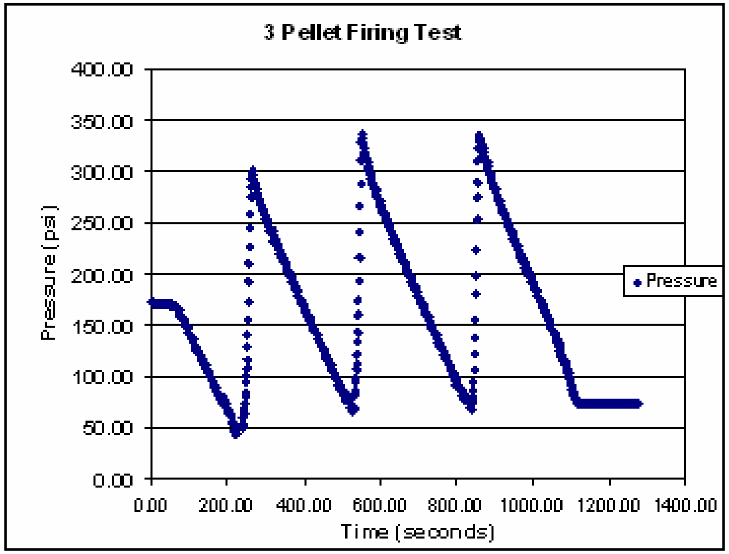


Jadoo Power Systems, Joint Service Power Expo, 2007, A. Wallace

Ammonia Borane

Core Attributes

- **Pellet Based Ammonia Borane**
- **12-14% Hydrogen Well Demonstrated**
- **System Packaging Under Development**



Significant Opportunity for Hydrogen Storage Options

Surveillance Robotics

Un-manned Aerial Vehicle

Military Communications

Professional Broadcast

Moving Forward with Fuel Cells: Army CERDEC Development and Demonstration Progress

Beth Bostic
US Army CERDEC Fuel Cell Team Leader

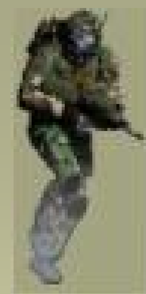
Agenda

- Current Program Paths
- Performance and Status Update
- Issues
- Future Program Paths and Demos

Mounted/Dismounted Soldier Power Army Technology Objective

FY05	FY06	FY07	FY08

FFW ATD   LW Blk III   PM-MEP STEP   PEO Soldier



TRL=5
2kW quiet power source
METRICS:
- **<150 kgs, JP-8**
- **Noise 69 dBA**

TRL=5
5 kW quiet power/cooling system
METRICS:
- **JP-8; 50% fuel savings**

TRL=5
250W Manportable field charger
METRICS:
- **Liquid fuel**
- **<10kgs**

TRL=5
20W Fuel Cell/rechargeable battery hybrid
METRICS:
- **Methanol fuel**
- **600whrs/kg @72 hrs**
- **1.5 lbs "dry"**

TRL=5
250W Manportable field charger
METRICS:
- **JP-8**
- **<10kgs**

TRL=6
Demo power mgnt at chip level
METRICS:
- **soldier electronics at 50% savings over current power levels**

TRL=6
20W fueled hybrid power source
METRICS:
- **Packaged fuel**
- **700whrs/kg @72 hrs**
- **1.5 lbs "dry"**

TRL=6
Demo improved soldier suite processors
METRICS:
- **soldier electronics at 75% savings over current power levels**

Pacing Technologies:

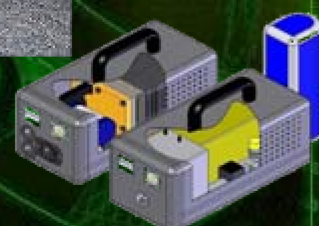
Meso-components	Burner control/Heat-driven cooling	Power Management Power integration

Fuel Cell Focus Areas

Soldier and Sensor Power (1-100W)	Battery Charging (100-500W)	Auxiliary Power Units (500W-10kW)
GOALS (FY08): ➢ 20 W, packaged fuel ➢ 700 Wh/kg (72-hr mission) ➢ 0.7 kg (dry)	**GOALS (FY08):** ➢ 250 W ➢ < 10 kg (dry) ➢ JP-8	**GOALS (FY08):** ➢ 2 kW, JP-8 fueled ➢ < 150 kg (dry) ➢ Noise < 69 dBA

Ultracell XX25 EVT

- 20W RMFC
- 1.1kg dry weight
- 23% system efficiency
- 360 W-hr/kg (72 -hr mission, 20W)



250W Battery Charger

- Methanol / water mix
- 15+kg system weight
- ~15% efficiency

GD / Aspen 5kW

- Logistics Fuel Reformer (CPOx)
- 799 ppm (wt) sulfur species in JP-8 tested successfully (no sulfur out)
- Reformate suitable for SOFC (<2.5% CO_2 + methane + acetylene, with balance 49%N_2, 24.5%H_2, and 24%CO)

Program Update: Current Status and Performance Metrics

Soldier Power Fuel Cell ATO Efforts

Ultracell Corporation

- 20W Reformed Methanol Fuel Cell
- Developed as part of ATO Program

Dimensions: 9.1’’ X 6.1’’ X 1.9’’
Start-Up Time: ~26 min consuming 18 g of fuel
System Dry Weight: 1.1 kg
Fuel Cartridge Weight: .325-.350 kg

24 hr mission weight : 2.25 kg
72 hr mission weight : 4.35 kg

Efficiency: 23.8% @ 20 watts
Fuel Cartridge Duration: 9 hours

72 hr mission energy density: 360 W-hours/kg

Ultracell Testing

- Tests completed at CERDEC - Fort Belvoir, VA
  - Fuel Consumption
  - Electrical Characterization
  - Orientation
  - Environmental
  - Max Power
  - Lifetime (in progress)
  - Thermal signature

- The 12 units CERDEC has received have logged over 1500 hours total, the most run hours logged by one unit is 300 hours

- Areas of Improvement and Future work
  - Thermal Management
  - Pump Development
  - Compressor Development
  - Reformer Work
  - Cartridge Development

Night Vision Compatibility

Smart Fuel Cell -DACP

DACP Goal - Develop a fuel cell with a similar form factor to the Li-145 battery that reduces weight and increases energy density for Soldier missions

- Dimensions: 9.75” x 2.31” x 3.06”
- System Dry weight: 1.18 kg
- Fuel cartridge: 500 ml / 0.47 kg
- 24 hr mission weight: 1.6 kg
- 72 hr mission weight: 2.6 kg
- Efficiency: 22.4%
- Fuel Cartridge Duration: ~24 hours
- Fuel is 100% methanol at low temp; water/methanol mix at high temp >40ºC
- 72 hour mission energy density 554 W-hr/kg

SFC Roadmap 2003-Present

System	Year	Weight (kg)	Operating Temp	Noise at 1 m dB(a)	Energy Density (wh/kg)	Orientation Independent
A25	2003	7.8	15° C - 35° C	40	150	N
C25	2004	1.7	1° C - 30° C	40	219	N
C20-MP	2005	2.0	5° C - 30° C	45	373	N
C20-D	2005	2.0	5° C - 50° C	45	259	N
FCPS	2006	1.2	1° C - 35° C	42	553	N
Alpha I	2007	1.4	Not Enough Information			N

A25

C20 – D / MP

Alpha I

C25

FCPS

AMI - Collaboration Efforts

CERDEC leveraged DARPA and SOCOM work with AMI and plans on future collaboration efforts.

Power:	20 W
Start Up Time:	20 minutes
Dimensions:	11.6’’ X 3.7 ’’ X 5.11’’
System Weight:	1.55kg
Fuel Cartridge Weight:	0.406kg
24 hr mission weight:	1.95 kg @ 20 Watts
72 hr mission weight:	2.77 kg @ 20 Watts
Fuel Cartridge Duration:	25 hours @ 20 Watts
Energy Density:	520 W-hours/kg (72 hrs@ 20 watts)

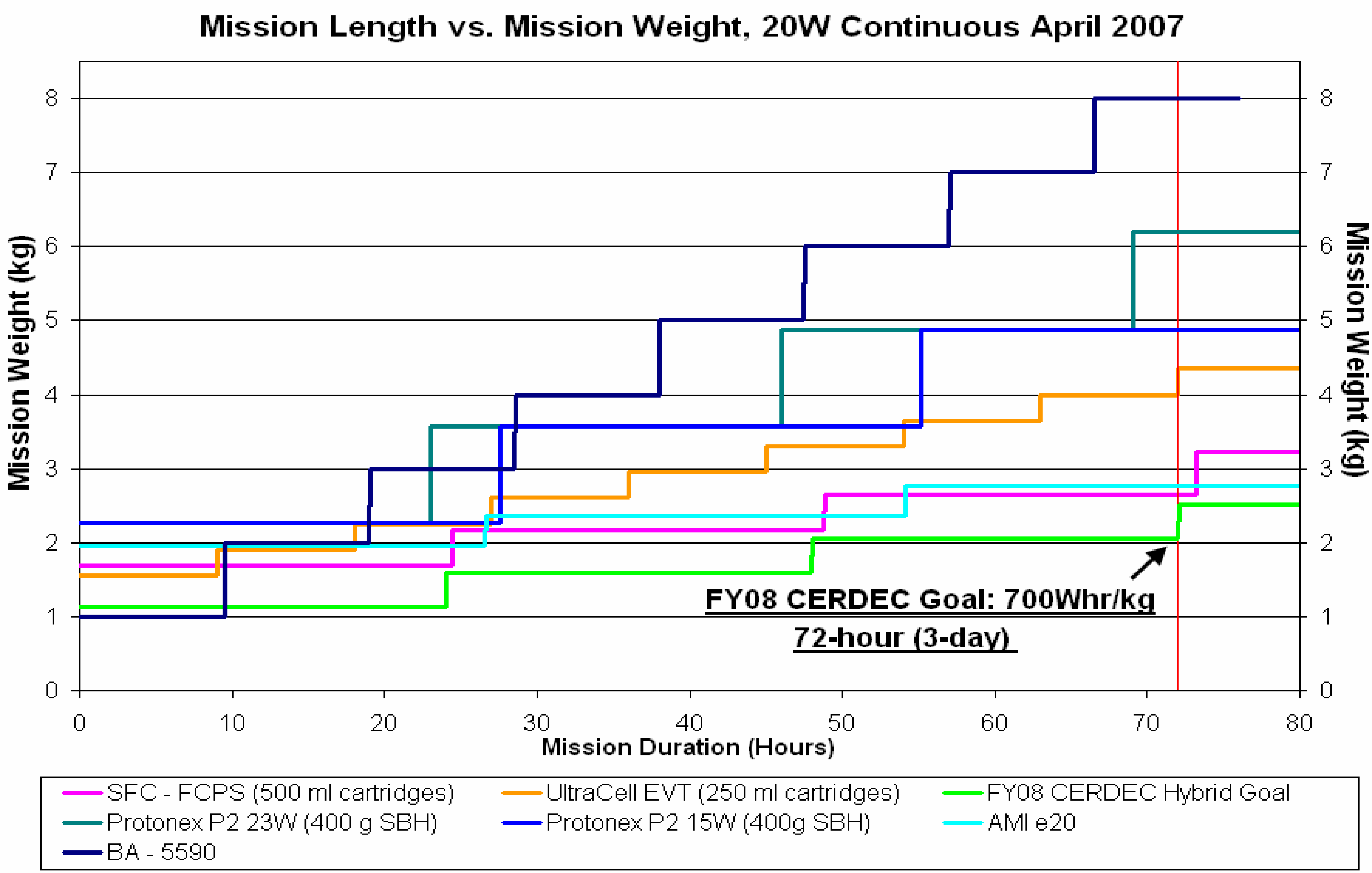
Protonex P2 ~ $NaBH_4$ PEMFC

In Testing with CERDEC
Rated 30W continuous
PEFC with Sodium Borohydride Fuel

Dimensions:	7.2’’ X 7.2’’ X 3.6’’
Start Up Time:	<1 min.
System Dry Weight:	0.96 kg
Fuel Cartridge Weight:	1.32 kg (hydrated)
24-hr Mission Weight :	3.60 kg
72-hr Mission Weight :	6.24 kg

24-hr, 30W Mission Energy Density:
200 W-hours/kg
72-hr, 30W Mission Energy Density:
350 W-hours/kg

Soldier Power Competition



Mid-Range Fuel Cell ATO Efforts

Idatech

- 250W Reformed Methanol Fuel Cell
- Developed as part of ATO Program
- Application is a forward field battery recharger and stand-alone 250W power source

Dimensions: 13.5 x 6.25 x 19.1 inches

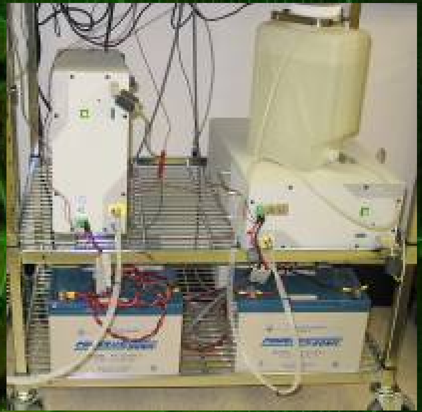
Weight: ~15kg

Efficiency: 15.4% @ 200W

Fuel Consumption: 500ml/hr

Idatech Testing

- Tests completed at CERDEC - Fort Belvoir, VA
  - Fuel Consumption
  - Electrical Characterization
  - Orientation
  - Environmental
  - Max Power
  - Thermal Signature
  - Acoustic Signature



- Two units at CERDEC have logged 140 and 103 hours
- Life Testing at Idatech reports 1240 hours of operation

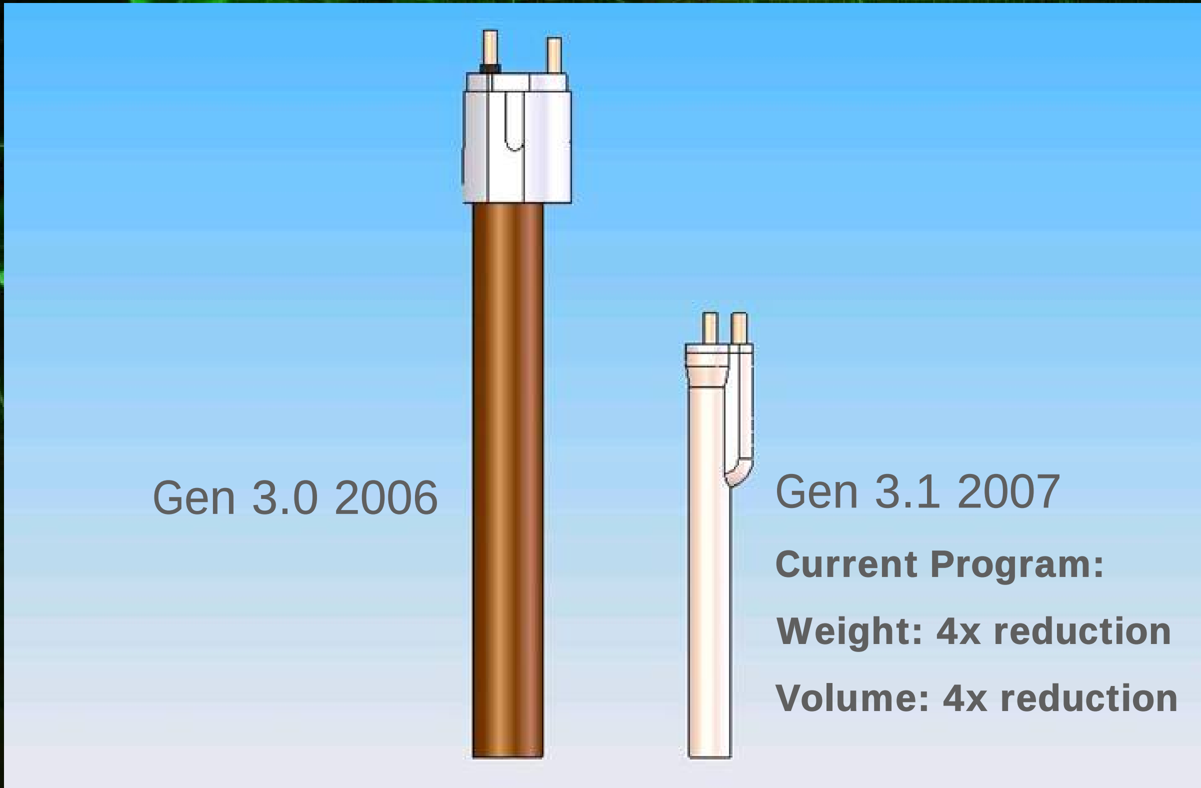
- Future Work will focus on
  - Increased system efficiency and reliability
  - System weight and volume reduction
  - Integrated starting capability
  - Study system weight and volume savings for single box configuration vs. modular

CellTech Power
Direct JP-8 Conversion Program

Liquid Tin Anode Solid Oxide Fuel Cell

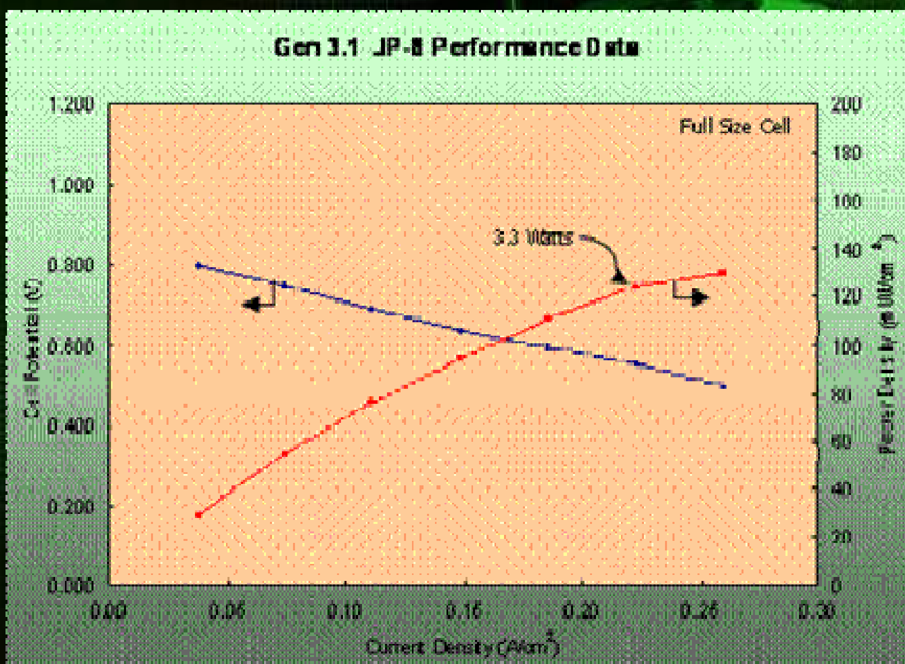
Program goals:

- JP-8 direct conversion
- 100 mW/cm^2
- 10 thermal cycle
- 28% eff @40mW/cm^2
- 30 min heat up
- 3 watt for single cell



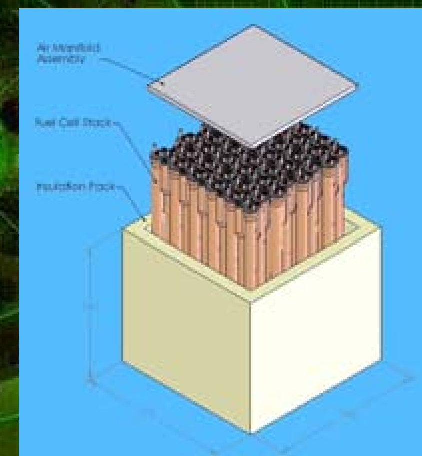
500 Watt Direct JP-8 Battery Charger

Recent Results for Direct JP-8
(single cell)
120 mW/cm²
3.3 watt
27% @70 mW/cm²



System Projection

@100 mW/cm²

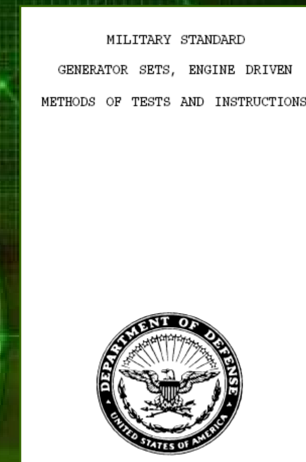


System kg- Dry	14.2
System Liters	16.9
Efficiency	25%
5 Days Fuel kg	20
Mission Wh/kg	1748

The Issues

Testing Specifications

- Operating and storage temperatures (-30°C to 50°C)
- Shock and vibration, drop test
- Acoustic & Thermal Signatures → Non-Detectability
- Humidity (high and low); rain and moisture, altitude
- EMI
- Electrical characterization, including peak power durations
- Thermal Cycling
- Start and Stop scenarios and durations
- Air side contamination resistance
- Human factors → user friendly
- Reliability
- Maintainability


MILITARY STANDARD

GENERATOR SETS, ENGINE DRIVEN

METHODS OF TESTS AND INSTRUCTIONS






Temperature Extremes

<u>Baghdad 691734</u>

Max Temp:	51 °C
R.H @ Max Temp:	6%
Lowest Recorded R.H:	5%
Average Temp. [Annual]:	24 °C
Average R.H. [Annual]	39%

Data Courtesy of:
Paul F. Krause, Ph.D.
U.S. Army Topographic Engineering Center

Technical Challenges

Across the Board…

- Rugged System, durability in harsh environments
- Reduce System Size and Weight
- Reliability
  - Balance of Plant Components
  - Air side contamination
- Water Management
- Reduce Acoustic and Thermal Signatures
- Orientation independent operation
- Power Quality
- Unit Cost

Plans for this Year

Activities

- PM C4ISR OTM Demo – Ft. Dix, NJ
  - Sensor Applications
  - Robotics Applications
  - Future Force Warrior
- Safety Assessment Reports
  - Currently Ultracell and SFC have limited safety approval for field testing
- Field Demos and Testing
  - Currently initiated mostly by Industry

Fort Dix Demonstration 2006

Programmatic Plans

- DARPA Robust Portable Power Sources Program
- Working on development of **FY09** ATO
  - Potentially looking at smaller power (sensors)
  - Fuel cells in 50W and 75W range
  - Fuel Cell for Robotics power
  - Targeting specific applications, not just areas

Conclusion

- The Army is looking for **total system solutions & appropriate applications.**
- Smaller systems are closer than larger systems to be transition ready.
- Maximize functionality and run-time of military power sources.
- Past year has show rapid development and significant improvement towards meeting the Soldiers need.
- CERDEC Testing shows major areas of development:
  - Reliability
  - Ruggedization
  - Efficiency
  - Light weight & compact
  - Energy Density

Questions?

The Next Level of Intelligent Power Management & Distribution

Todd Reffey, Technical Sales Engineer
Energy Technologies, Inc.
Mansfield, OH 44902 USA
treffey@ruggedsystems.com

Limits of Previous Power Management & Distribution Approaches:

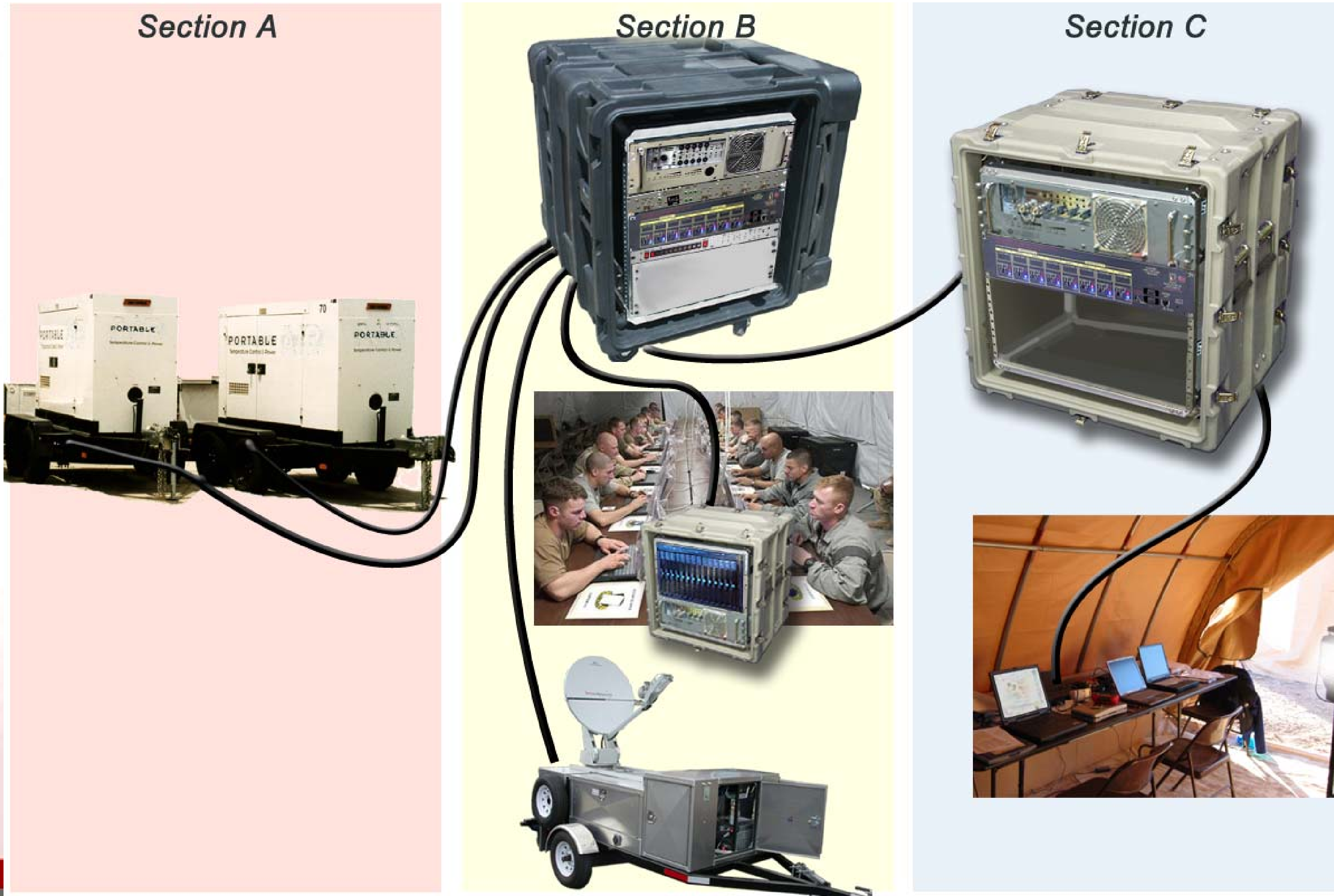
- Minimal real-time capability.
- Limited man-machine interfacing.
- Lacks the ability to improve power quality.
- Generally limited to 1 AC voltage and frequency or 1 DC voltage.
- Failure to provide a detailed history of power conditions that allow pro-active control and power load shedding.
- Cannot provide information or take intelligent action based on environmental conditions or external events.
- No automated notification for scheduling maintenance requirements.

The Next Level of Intelligent Power Management & Distribution

A Solution: TIPS (Tactical Intelligent Power System)

- Integrated hardware/software solution providing total power management capabilities.
- Modular design
- Manages different AC or DC voltages and frequencies
- Interface can be SNMP, HTTP, or Telnet using Ethernet or serial COM ports.
- Real-time and historical information
- Priorities, alarm thresholds and control actions.
- Optional power conditioning modules can clean up available power for sensitive electronics.

The Ability to Condition, Monitor and Control Power



The Next Level of Intelligent Power Management & Distribution

TIPS Primary Modules:

- **The SNMP/HTTP Controller (the heart of the application)**
- **The System Configuration Control Panel**
- **Intelligent PDU Modules with Output Feed Control**
- **AC Line Conditioner Module/s**
- **DC Line Conditioner Module/s**
- **Battery Backup Module/s**

The Next Level of Intelligent Power Management & Distribution

TIPS Secondary Modules

(Master/Slave Configuration)

- Secondary SNMP/IP Controller
- Intelligent PDU Modules
- AC Line Conditioner Module/s
- DC Line Conditioner Module/s
- Battery Backup Module/s

The Next Level of Intelligent Power Management & Distribution

SNMP/IP Controller

Addresses configuration, monitoring & control functions.

RS-232 interface for a direct connection

TCP/IP Ethernet connection - allows modules (Control Panels, Line Conditioners, Battery Modules, Generator Interface Controls and PDU's) to be controlled from the main interface & potentially remote locations if IP connection is provided at the controller.

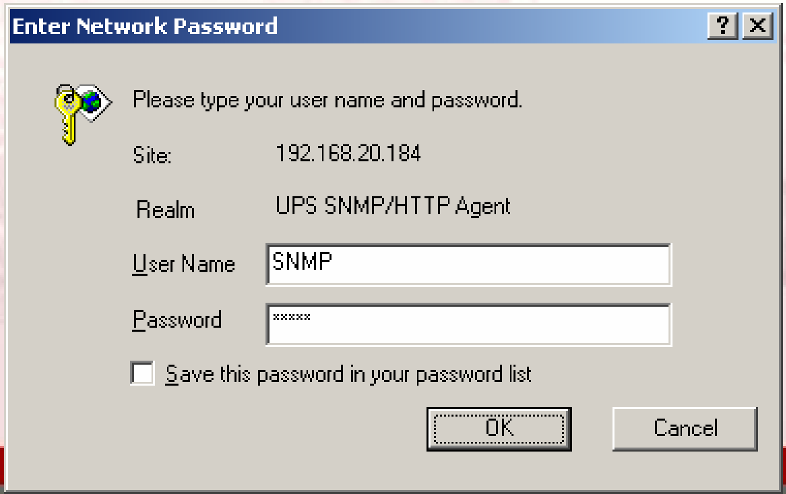
The Next Level of Intelligent Power Management & Distribution

SNMP/ IP Controller

SNMP-enabled devices can spontaneously inform the SNMP manager of important events or alerts.

The SNMP/HTTP controller incorporates HTTP 1.1 (64 bit encrypted) authentication. This level of security adds user name/password verification and allows the administrator to disable any unused interfaces minimizing possible system communication errors & intrusions.

Allows for an Administrator Login & Multiple Users.

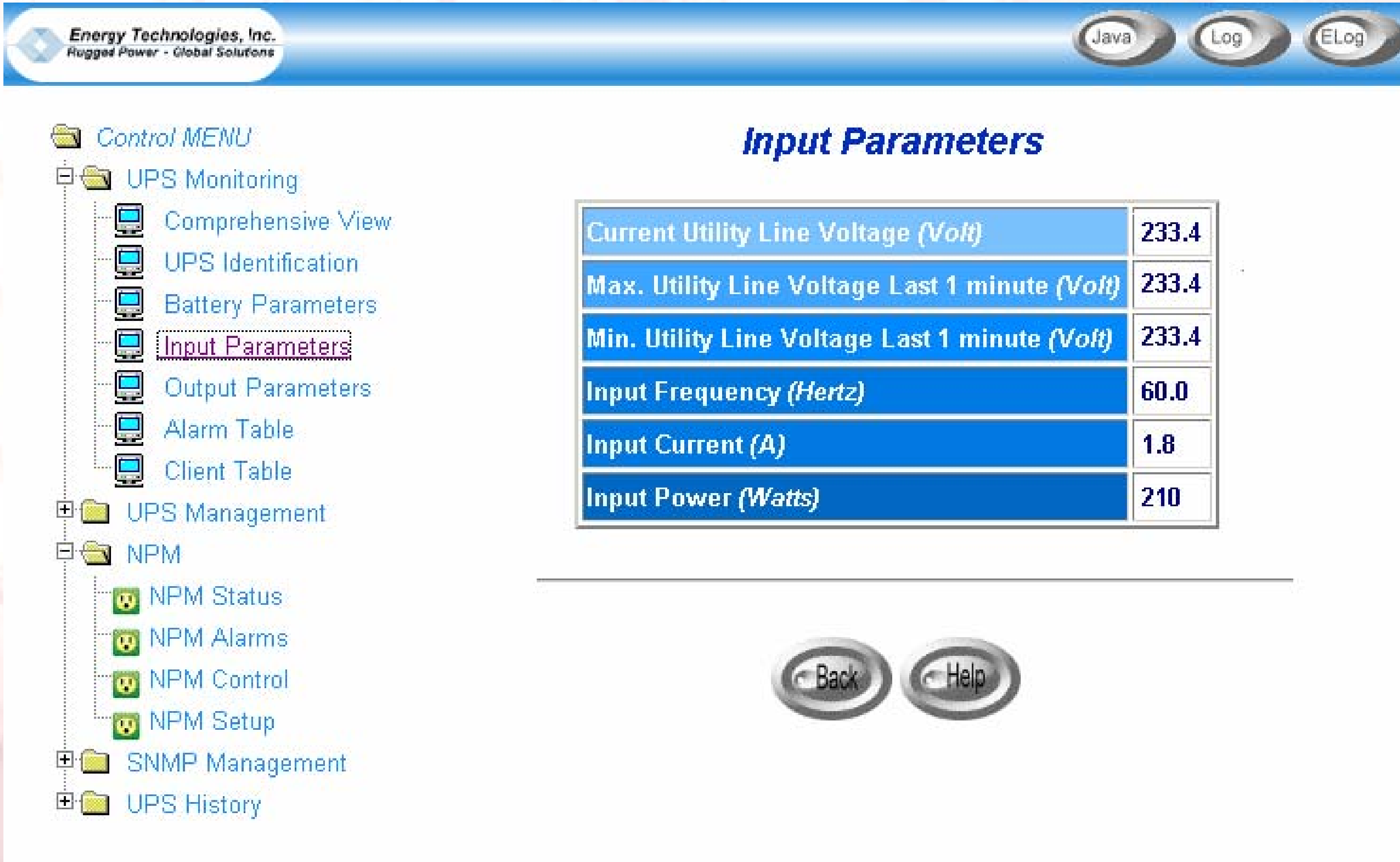


The Next Level of Intelligent Power Management & Distribution

The Controller addresses a multitude of configurations & controlling functions:

- Interface to Line Conditioner
- Monitoring and Status of Battery Module
- Control and Configuration of PDU
- Management of Critical vs. Peripheral Loads
- Load Sequencing for Start-up and Shutdown
- Dynamic Load Shedding
- Max Designated Load Levels
- Load Lock Out
- Interface Control
- Load Cycling
- Configuration Status
  (Conditioned Loads, UPS Loads, Un-Conditioned Loads)
- Optional Engine Control & Monitoring w/ TPP Module

The Next Level of Intelligent Power Management & Distribution



The Next Level of Intelligent Power Management & Distribution

Energy Technologies, Inc.
Rugged Power - Global Solutions

Java Log ELog

Control MENU

- UPS Monitoring
  - Comprehensive View
  - UPS Identification
  - Battery Parameters
  - Input Parameters
  - Output Parameters
  - Alarm Table
  - Client Table
- UPS Management
- NPM
  - NPM Status
  - NPM Alarms
  - NPM Control
  - NPM Setup
- SNMP Management
- UPS History

Output Parameters

Output Source	Normal
Output Frequency *(Hertz)*	60.0
Output Voltage *(Volt)*	244.0
Output Current *(A)*	1.2
Output Power *(Watts)*	145

Back Help

The Next Level of Intelligent Power Management & Distribution

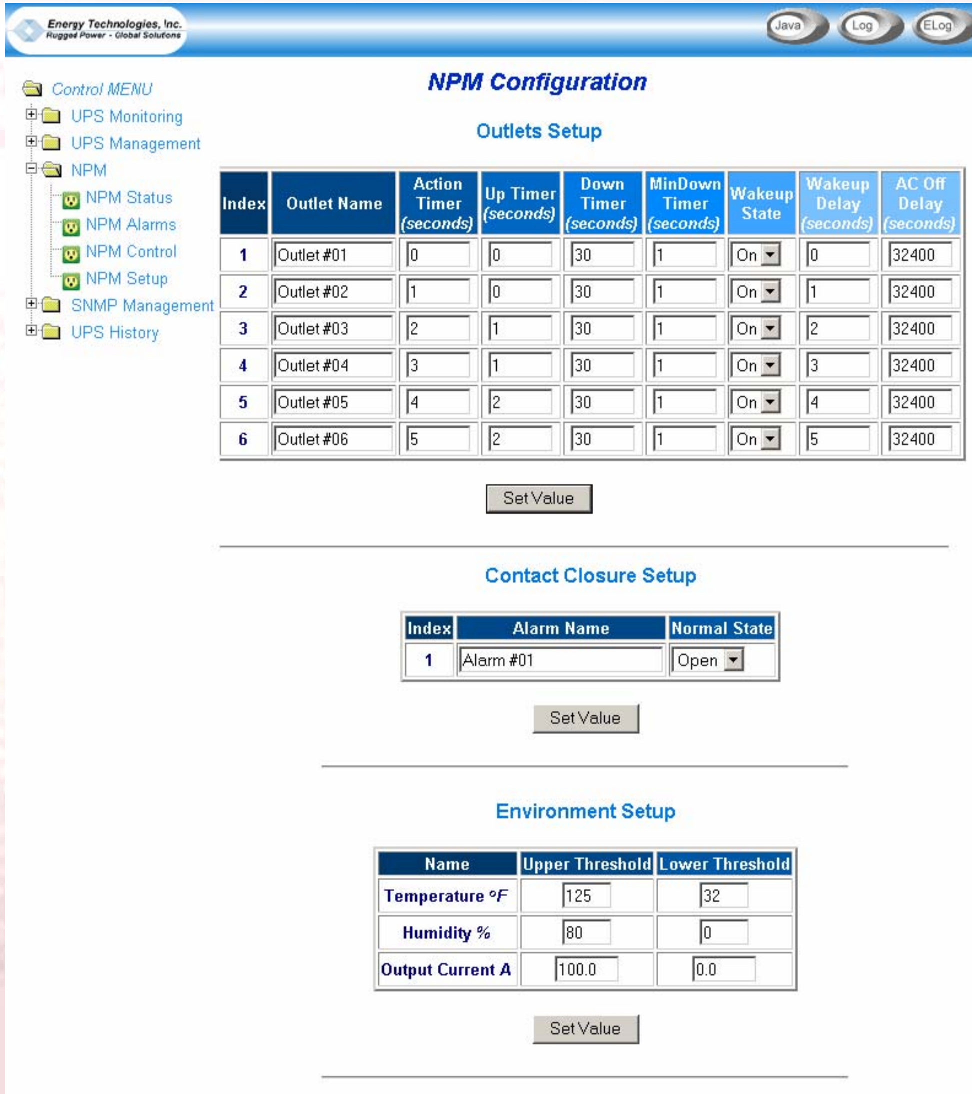
Each PDU outlet can be addressed
Each PDU can have up to 16 controlled outlets

The settings for each outlet are as follows:

- None
- Cancel
- On Immediately
- On By Default Timer
- On By Action Timer
- Off By Default Timer
- Off by Action Timer
- On then Off by Action Timer
- On then Off by Default Timer
- Cycle Immediately
- Off Immediately
- Off Then On by Default Timer

The Next Level of Intelligent Power Management & Distribution

The Next Level of Intelligent Power Management & Distribution



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Java Log ELog

Control MENU
- UPS Monitoring
- UPS Management
- NPM
  - NPM Status
  - NPM Alarms
  - NPM Control
  - NPM Setup
- SNMP Management
- UPS History

NPM Configuration

Outlets Setup

Index	Outlet Name	Action Timer (seconds)	Up Timer (seconds)	Down Timer (seconds)	MinDown Timer (seconds)	Wakeup State	Wakeup Delay (seconds)	AC Off Delay (seconds)
1	Outlet #01	0	0	30	1	On	0	32400
2	Outlet #02	1	0	30	1	On	1	32400
3	Outlet #03	2	1	30	1	On	2	32400
4	Outlet #04	3	1	30	1	On	3	32400
5	Outlet #05	4	2	30	1	On	4	32400
6	Outlet #06	5	2	30	1	On	5	32400

Set Value

Contact Closure Setup

Index	Alarm Name	Normal State
1	Alarm #01	Open

Set Value

Environment Setup

Name	Upper Threshold	Lower Threshold
Temperature °F	125	32
Humidity %	80	0
Output Current A	100.0	0.0

Set Value

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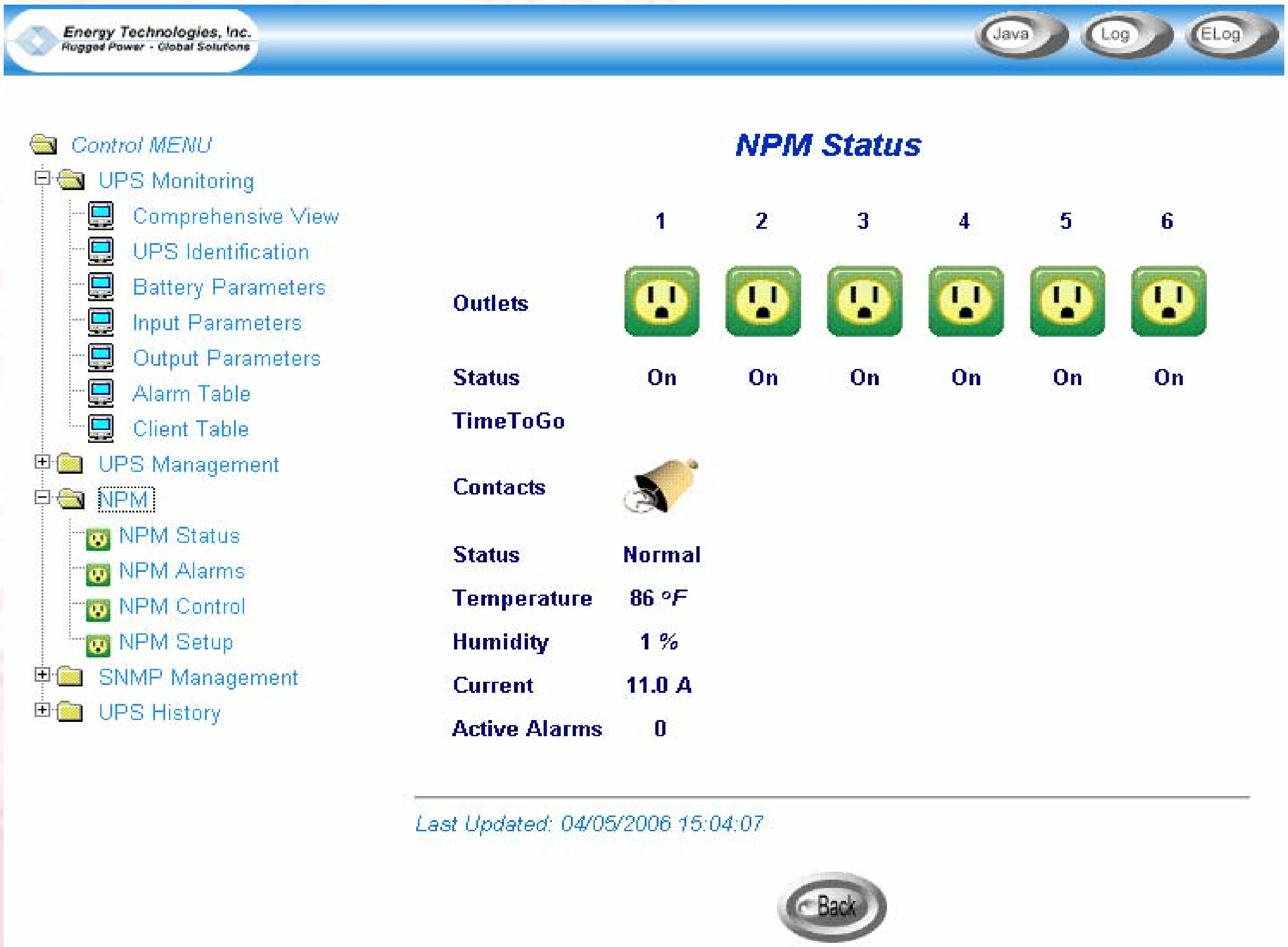


The Next Level of Intelligent Power Management & Distribution

The Next Level of Intelligent Power Management & Distribution

System Configuration Control Panel

Provides the configuration control to apply a line conditioner to the total load or partial load.

Allows the end-user to connect a battery module to the line conditioner creating a UPS for the designated distribution or direct connected load.

Depending upon which power needs to be conditioned or passed on to the PDU's, the control panel can pass the generated (or grid) power to a specific local or remote PDU.

The Control Panel is a manual control interface with a switching configuration and/or circuit breaker connected to the line conditioner, UPS and distribution to the local and/or remote PDU modules.

The Next Level of Intelligent Power Management & Distribution

AC Line Conditioner Module

The AC Line Conditioner is a rugged on-line conditioner that continuously provides conditioned AC output at the rated load level. This is a precise controlled conditioner for voltage and frequency.

120/208/240 VAC

85-270 VAC Auto Ranging

Single Phase/Three Phase

50, 60, & 400 Hz Frequencies Standard or Selectable

Other Voltages & Frequencies Optional

The Next Level of Intelligent Power Management & Distribution

DC Line Conditioner Module

The DC Line Conditioner is a rugged on-line conditioner that continuously provides conditioned DC output at the rated load level.

3.3V,5V,12V,24V, & up to 125VDC Voltages are available.

Other Voltages Optional.

The Next Level of Intelligent Power Management & Distribution

Battery Module

The Battery Module is a self-contained battery pack utilizing VRSLAB battery technology. The modules can be configured for single or multi-string application.

Modules can provide from 5 minutes to 24 hours of back up.

The only limitations are the amount of space available and the amount of total system acceptable weight.

The Next Level of Intelligent Power Management & Distribution

Intelligent PDU Module

• Interfaces directly with the main control panel to each of the PDU outputs. The logic is interfaced via the IP interface with SNMP.

• PDU's can be configured for 8 or 16 outputs.
1U height PDU can have 8 NEMA 5-15 outputs with cord bails
2U height PDU can have 16 NEMA 5-15 outputs.
Other connectors can be provided

Intelligent PDU Modules with Output Feed Control

The Output Power Feed Control is both a manual and automatic control. The main purpose of the module is to provide both a disconnect location and to protect the system from sudden current overloads. This module contains the control contactors that interface into the main controller to provide remote command shut down and remote PDU disconnect functions.

The Next Level of Intelligent Power Management & Distribution

Intelligent PDU Module

• The TIPS PDU can control a variety of load currents & voltages, including single phase, three phase & DC.

• Outlets may even be grouped so a single command can control multiple subsystems. Useful to control N+1 configurations, where power to all outlets must be removed simultaneously.

• The TIPS PDU also has a main feature to provide effective EMI/RFI filtering, incorporating both common mode and differential mode interference reduction.

The Next Level of Intelligent Power Management & Distribution

Secondary SNMP/ IP Controller

The Secondary Controller is a slave controller interfacing with the main controller.

It has similar capabilities but is configured to Reply and Execute Configuration Requirements and settings from the main controller.

If communication is lost from the main controller the secondary controller will run in a “Free Run Mode”.

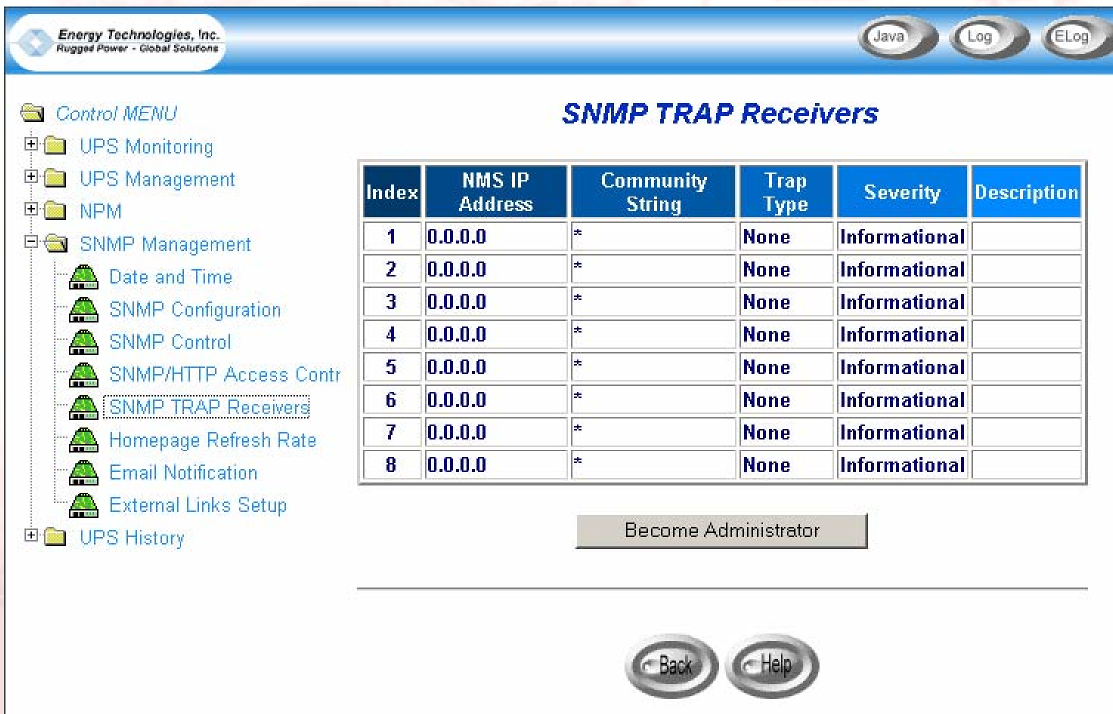
A local IP port is provided to gain required access in the fault condition to modify any configuration settings previously sent by the main controller. The secondary controller maintains a local history log and alarm log.

Upon request from the main controller the secondary controller will forward these files to the end user if the appropriate administrative login is utilized

The Next Level of Intelligent Power Management & Distribution

Network Interfacing with the TIPS

10/100 Base T Internet Protocol connection used to transport SNMP. Utilized with any IP access provided to the main controller. Traps can be sent to compile Historical files to the IP addresses configured by the end user for remote use



Index	NMS IP Address	Community String	Trap Type	Severity	Description
1	0.0.0.0	*	None	Informational	
2	0.0.0.0	*	None	Informational	
3	0.0.0.0	*	None	Informational	
4	0.0.0.0	*	None	Informational	
5	0.0.0.0	*	None	Informational	
6	0.0.0.0	*	None	Informational	
7	0.0.0.0	*	None	Informational	
8	0.0.0.0	*	None	Informational	

Network Interfacing with TIPS

Telnet - a secondary interface for local (and potentially remote) access.

Menu based approach and allows access to all information in a more limited basis

RS232 backup interface is provided for localized access and utilizes a similar menu approach as the Telnet interface.

Most useful when configuration issues arise with IP addressing errors that will not allow access via the IP/SNMP or Telnet interface.

```
+==========================================
====================================+
|                  [ SNMP Configuration
Utility Main menu ]                   |
+==========================================
====================================+

Enter Password: *****

+==========================================
====================================+
|                  [ SNMP Configuration
Utility Main menu ]                   |
+==========================================
====================================+
   1. SNMP Information
   2. UPS Parameters<- Set UPS model,
type.
   3. Access Control Table<- control who
has access via IP.
   4. Trap Receiver Table<- Control where
the TRAPS are sent.
   5. Reset Configuration To Default<-
Reset SNMP some values. Not IP
   6. Restart SNMP<- Restart
   7. Receptacle Status, Configuration and
Control
   0. Exit

Please Enter Your Choice => 1
```

Historical Tracking

The Traps of the SNMP protocol are routed to an IP address designated as "Trap Receivers". The Structure of a Trap is of a nature that it contains a data element that can be interpreted via the MIB and the SNMP control console software. This data element then is placed in a first in first out file structure.

The Trap Data Element is then placed in the appropriate Trap Receiver File and can be called up by the authorized Administrative Login and Password.

The Next Level of Intelligent Power Management & Distribution

Logs Traps Rules Actions MIB Manager User Manager Settings About Help Logout

THIS IS EVALUATION-ONLY VERSION OF TRAP CONSOLE. IT CAN BE USED ONLY FOR EVALUATION WHETHER TO PURCHASE AN ONGOING LICENSE.

Use this page to view logs generated by Trap Console.

Select Log:	Write trap to the log file	Display Log Delete Log
Autorefresh:	Enabled: ☐ Every 10 seconds.	Set

```
August 19, 2004 1:55:24 PM EDT: (192.168.20.182): mib-2.855.4.1.5 mib-2.855.4.1.2.3.1(1), mib-2.855.4.1.2.3.4(AC Outlet #01), mib-2.855.4.1.2.3.2(1), mib-2.855.4.1.2.
August 19, 2004 1:02:50 PM EDT: (192.168.20.182): mib-2.855.4.1.4 mib-2.855.4.1.2.6.1(3), mib-2.855.4.1.2.6.2(Temperature out of range)
August 19, 2004 1:02:34 PM EDT: (192.168.20.182): mib-2.855.4.1.3 mib-2.855.4.1.2.6.1(3), mib-2.855.4.1.2.6.2(Temperature out of range)
August 19, 2004 1:02:17 PM EDT: (192.168.20.182): mib-2.855.4.1.4 mib-2.855.4.1.2.6.1(3), mib-2.855.4.1.2.6.2(Temperature out of range)
August 19, 2004 1:01:37 PM EDT: (192.168.20.182): mib-2.855.4.1.3 mib-2.855.4.1.2.6.1(3), mib-2.855.4.1.2.6.2(Temperature out of range)
August 19, 2004 1:01:28 PM EDT: (192.168.20.182): mib-2.855.4.1.4 mib-2.855.4.1.2.6.1(3), mib-2.855.4.1.2.6.2(Temperature out of range)
August 19, 2004 12:59:44 PM EDT: (192.168.20.182): mib-2.855.4.1.5 mib-2.855.4.1.2.3.1(7), mib-2.855.4.1.2.3.4(DC Out #1 & #2), mib-2.855.4.1.2.3.2(2), mib-2.855.4.1.
August 19, 2004 12:59:41 PM EDT: (192.168.20.182): mib-2.855.4.1.5 mib-2.855.4.1.2.3.1(5), mib-2.855.4.1.2.3.4(AC Outlet #05), mib-2.855.4.1.2.3.2(2), mib-2.855.4.1.2
August 19, 2004 12:59:37 PM EDT: (192.168.20.182): mib-2.855.4.1.5 mib-2.855.4.1.2.3.1(3), mib-2.855.4.1.2.3.4(AC Outlet #03), mib-2.855.4.1.2.3.2(2), mib-2.855.4.1.2
August 19, 2004 12:59:33 PM EDT: (192.168.20.182): mib-2.855.4.1.5 mib-2.855.4.1.2.3.1(1), mib-2.855.4.1.2.3.4(AC Outlet #01), mib-2.855.4.1.2.3.2(2), mib-2.855.4.1.2
August 19, 2004 12:58:58 PM EDT: (192.168.20.182): mib-2.855.4.1.3 mib-2.855.4.1.2.6.1(3), mib-2.855.4.1.2.6.2(Temperature out of range)
August 19, 2004 12:58:50 PM EDT: (192.168.20.182): mib-2.855.4.1.4 mib-2.855.4.1.2.6.1(3), mib-2.855.4.1.2.6.2(Temperature out of range)
August 19, 2004 12:58:01 PM EDT: (192.168.20.182): mib-2.855.4.1.3 mib-2.855.4.1.2.6.1(3), mib-2.855.4.1.2.6.2(Temperature out of range)
August 19, 2004 12:57:28 PM EDT: (192.168.20.182): mib-2.855.4.1.4 mib-2.855.4.1.2.6.1(3), mib-2.855.4.1.2.6.2(Temperature out of range)
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August 19, 2004 12:56:39 PM EDT: (192.168.20.182): mib-2.855.4.1.5 mib-2.855.4.1.2.3.1(2), mib-2.855.4.1.2.3.4(AC Outlet #02), mib-2.855.4.1.2.3.2(1), mib-2.855.4.1.2
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The Next Level of Intelligent Power Management & Distribution

Remote Notifications of Maintenance & Compliance of Maintenance Performed

Logging & timing of maintenance is not overlooked.

Understanding what needs to be done on a preventative basis.

Avoid pitfalls of trouble free operation.

Stay ahead of the curve for increased demands for deployed equipment with continuous level of conditioned power.

User access to all performance including real time and date stamp enhances intelligent power management.

The Next Level of Intelligent Power Management & Distribution

Remote Notifications of Maintenance & Compliance of Maintenance Performed

The maintenance requirements of line conditioning equipment, UPS and PDU modules have been historically based on time frames. The air filters need to be changed in specific time window, the connections need to be inspected on a annual basis, the batteries need to be cycled on a bi-annual bases and the other elements all have time periods of operation prior to having maintenance of some level performed.

By utilizing the time and date stamping capabilities of the controller each of the defined maintenance items can be tracked. Once the threshold is triggered the console then can issue an IP message, a SMR to a wireless device, an Email to a specified address or an indicator on an auxiliary monitor panel.

The Next Level of Intelligent Power Management & Distribution

Remote Notifications of Maintenance & Compliance of Maintenance Performed

Once the maintenance is performed the controller requires the action to be authenticated and logs the action as complete and restarts the clock for the item.

Summary reports are compiled and once again can be sent via an IP message, a SMR to a wireless device or an Email to a specified address. Multiple notifications can all be configured to allow communications to a centralized maintenance facility along with the notification to supervisory personnel.

Additionally alarms and faults can be synchronized with the maintenance logs to aid in potential failure analysis.

The Next Level of Intelligent Power Management & Distribution

Remote Notifications of Maintenance & Compliance of Maintenance Performed

This feature set also allows for trouble shooting assistance by displaying trouble shooting trees based on the fault indication.

An additional documentation feature of the TIPS is eDoc™. This is an access USB port that contains the complete operational and engineering data for the system. This information can be accessed even if the power is completely down as the interface is based on a USB connection and is self powered from the local device, be that a PDA or Laptop

The Next Level of Intelligent Power Management & Distribution

In Summary

- The need for conditioned and monitored power can now be met with the TIPS.
- Field personnel can now focus on the tasks at hand without concern for the loss or degradation of the power source.
- Alarms and faults can be tracked and assistance can be provided at the indication of the alarm or fault.
- Historical data can be compiled and distributed to upper management and maintenance support centers.
- The existing concerns and trouble spots can be eliminated.
- The data support computers can now do their functions and the field personnel can configure and use the power to their advantage.

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The Next Level of Intelligent Power Management & Distribution

Thank you!

Protonex

Portable Power Sources: One Size Fits None

Phil Robinson

2007 Joint Service Power Expo
April 26, 2007

Protonex

Outline

- Introduction
- The "Typical Mission"
- Active Power Management
- Fuel Cell Technologies
- Battery Technologies
- Mission Profiling
- Summary

Mesoscopic Devices

POWERED BY Protonex

Mesoscopic Devices, LLC
merged with Protonex in April 2007

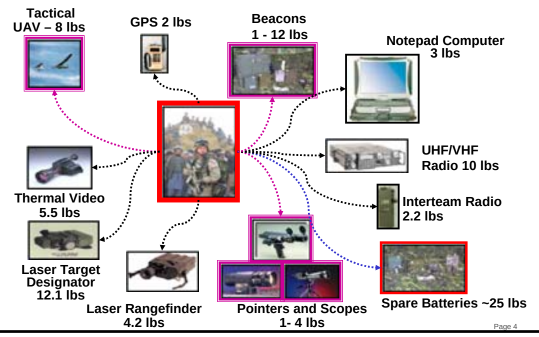
Protonex

Who Is Protonex?

- Supplier of Military Portable Power Systems
  - Fuel Cell Systems: PEM & SOFC
  - Fuel Processing: Chem. Hydride, Methanol, Propane, JP-8
  - 50W, 75W, 150W, 250W…
- Military Fuel Cell Contracts
  - AFRL, NRL, ARO, ONR, etc…
  - Power Management: AFRL

Protonex

The “Typical” Mission

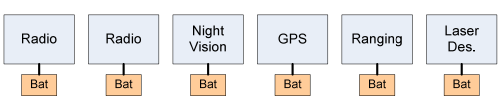


Protonex

The “Typical” Warfighter

Protonex

Typical Portable Power Scenario

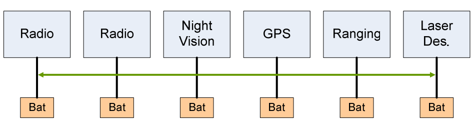


- BA-5590, BB-2590, LI-145, AA, Others…
- Need spares for all – no sharing or weight/cube optimization

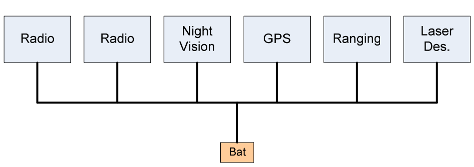
BA & TACP Learnings

- No two soldiers carry an identical complement of equipment
- A single warfighter varies his gear depending upon the mission
- Every soldier carries “too many batteries”
- Much carried energy remains unused – spares needed for all gear to ensure mission success

Active Power Management

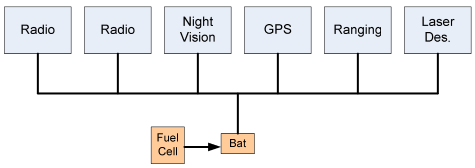


Active Power Management



Protonex

Active Power Management



Protonex

Protonex Power Manager

- Enables Single Energy Source
- Routes Power To Devices
- Wide Range Scavenger
- Mission Profiler

Protonex

Power Scavenger

- Input: 1.5V to 36V
- Direct Solar Blanket Support
- Maximize Rate / Maximize Efficiency
- Additive to Fuel Cell

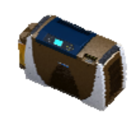
Protonex

Mission Profiling

Protonex

Fuel Cells: One Size Fits None

- Fully integrated power systems – fuel in, power out
- Supporting multiple fuel types
  - Hydrogen, Chemical Hydrides, Methanol, Propane, JP-8
- Hydrogen PEM fuel cell technology
- SOFC technology



Valta™ 250 Multi-Purpose APU

150W & 500W Power Generators

75W SOFC Power System

ProPack™ C50 Man-Portable Power

Protonex

Batteries: One Size Fits None

- **High Energy vs. High Power**
- Medipak Warrior-Pak
- MicroSun
- Li-145
- PTX-A123
- AA

Protonex

Summary

- Active Power Management Reduces Battery and Mission Weight Without Reducing Soldier Options
  - Shares power among multiple devices
  - Reduces wasted redundant “spares weight”
  - Incorporates wide range scavenging capability
  - Provides mission profiling and planning capability
- Compatible with multiple fuel cell and battery technologies
- Being Demonstrated in Protonex Booth

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Protonex

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Solid Oxide Fuel Cell Power Systems for Small UAVs

2007 Joint Service Power Expo
April 24-26 2007

Timothy LaBreche

Adaptive Materials, Inc.
4403 Concourse Drive, Suite C
Ann Arbor, MI 48108
734.302.7632

www.adaptivematerials.com

AMI Adaptive Materials Inc.

Outline

- About Adaptive Materials (AMI)
- AMI Technology & Systems
- Unmanned Aerial Vehicles Power Systems

About AMI

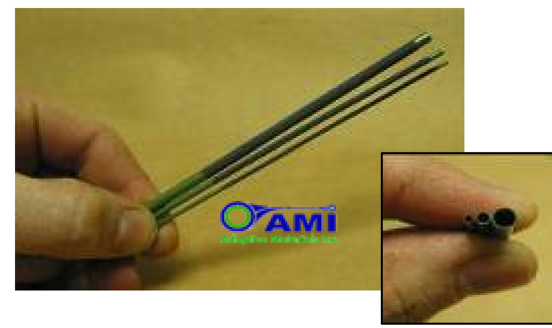
- Ann Arbor, Michigan
- Portable Solid Oxide Fuel Cells
- 25W, 50W and 150W Systems

e50

Technology

- Large Scale Power Generation
- Ceramic
- High Temperature ~700C

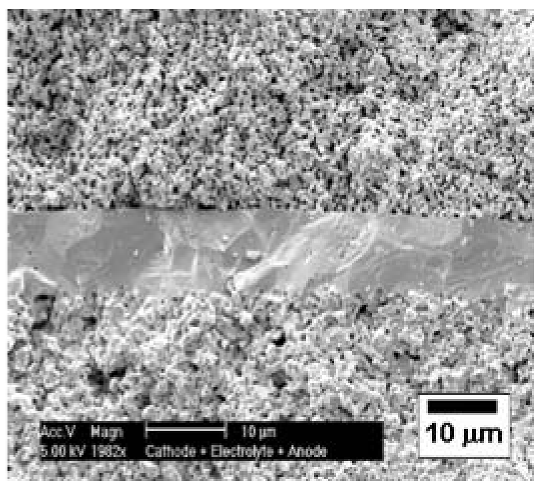
Micro-tubular Fuel Cells



Cathode
$(La_xSr_{1-x})MnO_3$ + YSZ

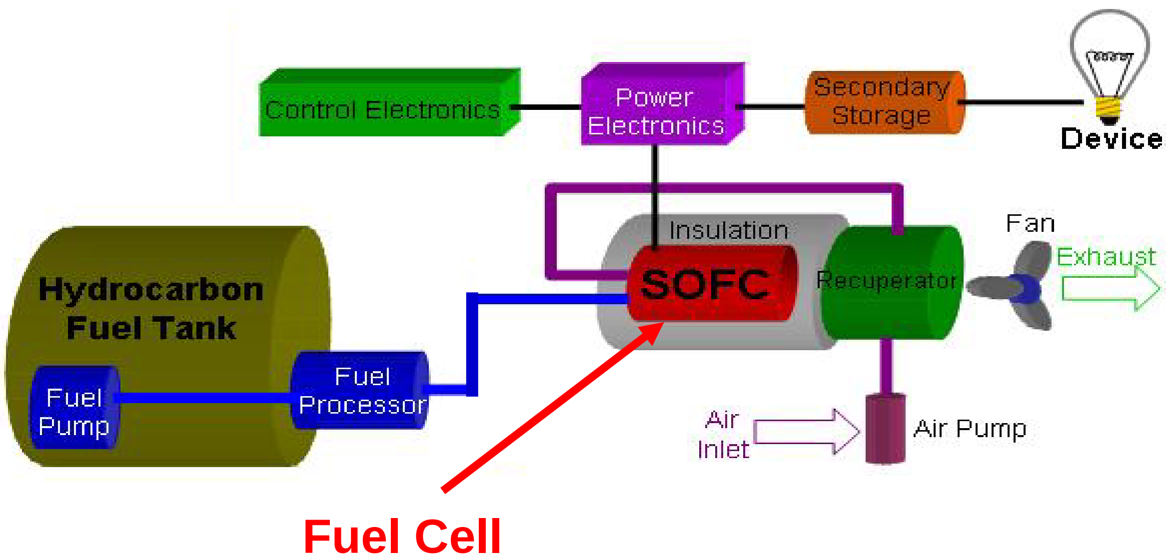
Electrolyte
10μm YSZ

Anode
Ni + YSZ



Technology

- Cells coupled into Stack
- Balance of Plant



AMI Adaptive Materials Inc.

Technology

Pilot scale manufacturing facility

- Capacity 100,000 cells per year
- Six Sigma based process improvement

SOFC = Fuel Flexibility

Propane Fuel Tank
9,675 Whr/kg

- **Maximum Portable Performance**
  - Highest energy density of any packaged fuel
- **100% Consumer Confidence**
  - DOT and UN certified tanks
    - Ground and air shipping
  - Global commodity
    - Existing supply chain and distribution
  - Low Cost

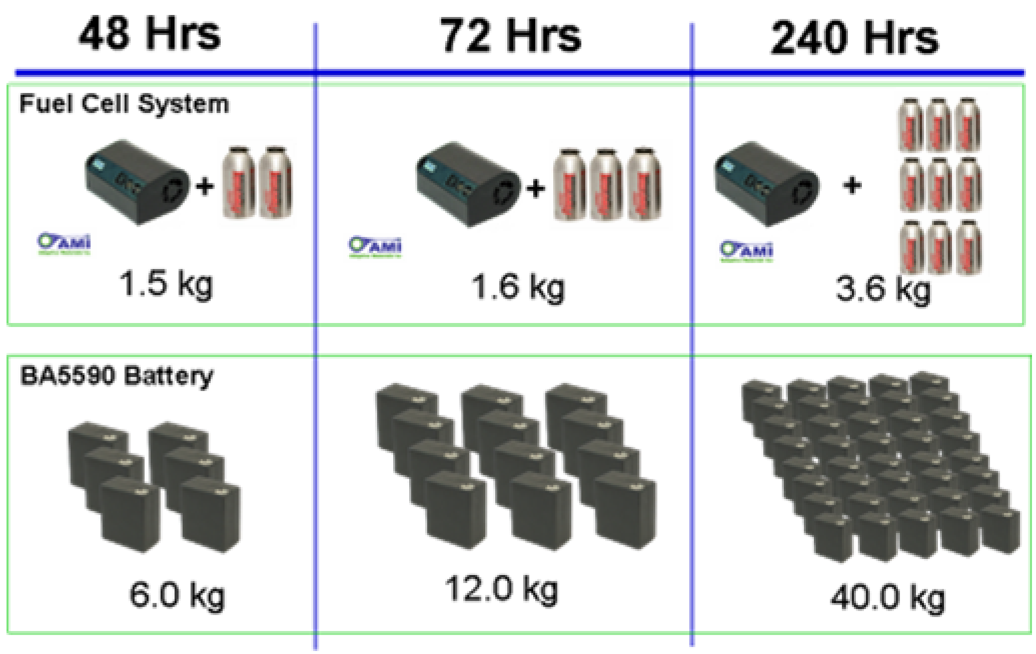
Global Commodity

25 Watt System –End of Palm Power

25W Palm Power

Specifications	
Dry Weight	0.96kg
Volume	1.6L
Net System Efficiency	20%

Specific Energy	
3 Day Mission W-hr/kg	**925**
10 Day Mission W-hr/kg	**1450**



Boomerang SOFC Generator

e50

- **50 Watt Continuous Power**
  - 12V
  - 100 Watt peak power
  - 25 Systems For Testing

- **System Specifications**
  - Dry system weight, less than 2.25 kg
  - Temperature -20ºC to 50ºC
  - Relative Humidity 5% to 95%
  - 12,500 feet with 0% power degradation
  - Dust and rain to military specification
  - Rapid Start Up < 15 minutes
  - Exhaust temperature <55ºC
  - Multiple fuel compatible

e50

Supply Chain Partners

Parker Hannifin for BOP Assemblies

e50

50W System

Specifications	
Dry Weight	2.25kg
Volume	4.5
Net System Efficiency	17%

Specific Energy	
3 Day Mission W-hr/kg	**775**
10 Day Mission W-hr/kg	**1200**

End of Life Testing

Goal = 300 Hours
Tested MTBF = 500 Hours

Rapid Start - Stop Testing

Goal = 100 cycles
Avg Cycles = 144 cycles

Small UAV SOFC Power Sources

- Background
- Power Source Comparison
- AMI UAV Power Systems
- AMI Proposed Development Efforts

Why Fuel Cell Powered UAVs?

- Quieter than internal combustion engines
- Far more efficient than small fractional horsepower engines
- Longer endurance than batteries
  - Much higher Whr/Kg
- Electric power for payload

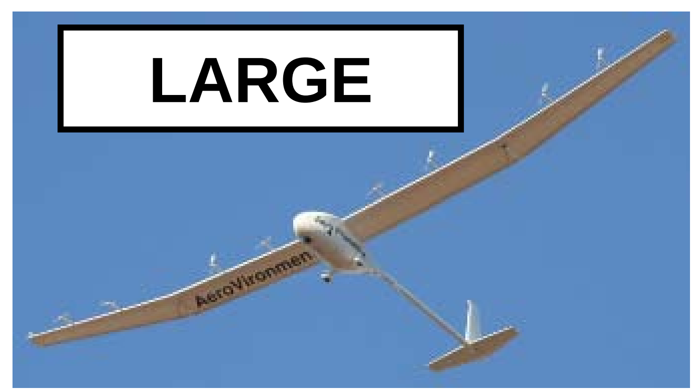
AMI Adaptive Materials Inc.

Hydrogen Fuel Cell Aircraft In All Sizes

- Aerovironment / Lynntech
  - Hornet Micro Air Vehicle 2003

SMALL

- NRL
  - 2005 - Spider Lion: 100 Watts: PEM : 2 meter span
- California State University, Los Angeles
  - 2006 – 500 Watts: PEM: 5.5 meter span
- Georgia Tech
  - 2006 – 500 Watts: PEM: 6.5 meter span
- Light Human Carrying Aircraft
  - UQM Technologies & BR&TE
- Aerovironment / NASA Dryden
  - Helios
  - HALE



http://www.avinc.com/publish/2006/01/05/1092_ _____________GO_Aerial_View2.jpg

AMI UAV Power System

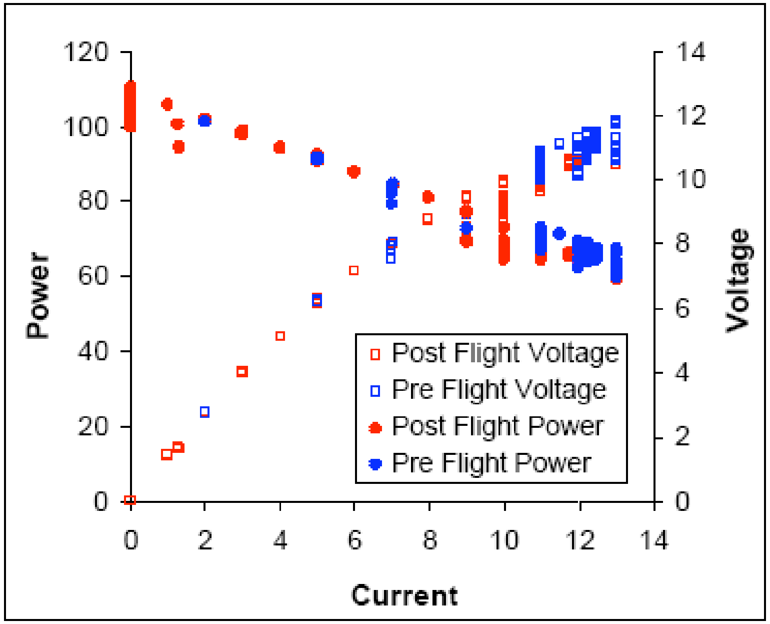
- ***Does not use Hydrogen***
  - Propane
  - Butane
- You can step outside this room and find fuel for the UAV power system within an hour.
- Lightweight
  - 1 kg power source: 4 hours 19 minutes
- Robust
  - Tolerates mishaps a.k.a. “Crashing”
  - We had a few issues with flying early on

SOFC UAV Power Systems are Robust

Early Test Flights - Video

SOFC Power Curves

Before and After Test Flights



Ceramic Not Always = Fragile

AMI Test Plane

Specifications	
Gross UAV Weight	6.75lbs
Level Flight Power Draw	*65 W
Fuel Cell Power	75-80W
Peak Power	**200W
Demonstrated Flight Time	11.5 Hrs
On Board Fuel	300g

*Documented from actual flight data
**Achieved through battery hybridization

All Ground Testing Specifications Based on Real Flight Data

Flight and Ground Test Results

Date	Event	Duration (Hrs)	Energy Density (W-hr/kg)
Feb 2005	Flight	0.25	-
Oct 2005	Flight	0.17	-
Jun 2006	Flight	1	60
Jun 2006	Flight	2.3	138
Jun 2006	Flight	4.3	250
Nov 2006	Autonomous Ground Test	11.5	680
Nov 2006	Autonomous Ground Test	8	443
Nov 2006	Autonomous Ground Test	8	440
Nov 2006	Autonomous Ground Test	8	414

Follow on program is pending with the Air Force.

Prior Performance

Generation I

250 Whr/kg

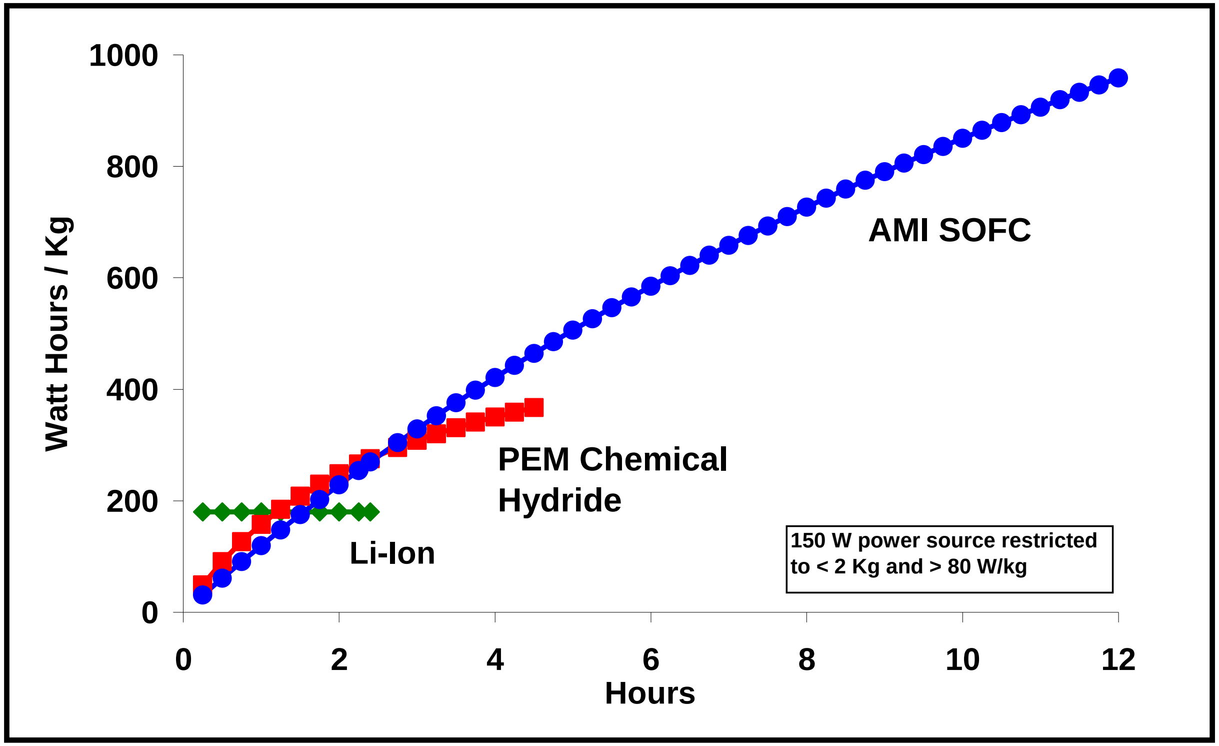
Generation II

660 Whr/kg

- Flight tests and bench top endurance runs to prove feasibility of SOFC UAV
- 4:19 flight represents a “world record” in fuel cell powered UAVs

Power Source Comparison

- **Whr/kg** are what sells fuel cells but a UAV still has to…
- Get off the ground … **W/kg**
- Be light enough to be hand launchable **< 2 Kg**



Next Generation UAV Power Source

		GEN II
		150W
Fuel Cell Power	80 W	150 W
Peak Power	200 W	400 W
Dry System Mass	1 kg	1.4 kg
Wet System Mass	1.4 kg	2 kg
Endurance	8 Hours	10 Hours
Energy Density (Whr/kg)	440	750
Full Tank Specific Power (W/kg)	**57**	**75**

Acknowledgements

- Department of Defense and other agencies
- The AMI team

Jack Adams
26 April 2007

MTS Technologies, Inc.

Management and Technical Services

2007 Joint Service Power Expo

Data Systems for Enhanced Power and Energy Management

MTS Technologies, Inc.

Management & Technical Services

John W. "Jack" Adams

Energy Sector Consultant

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MTS Technologies, Inc.

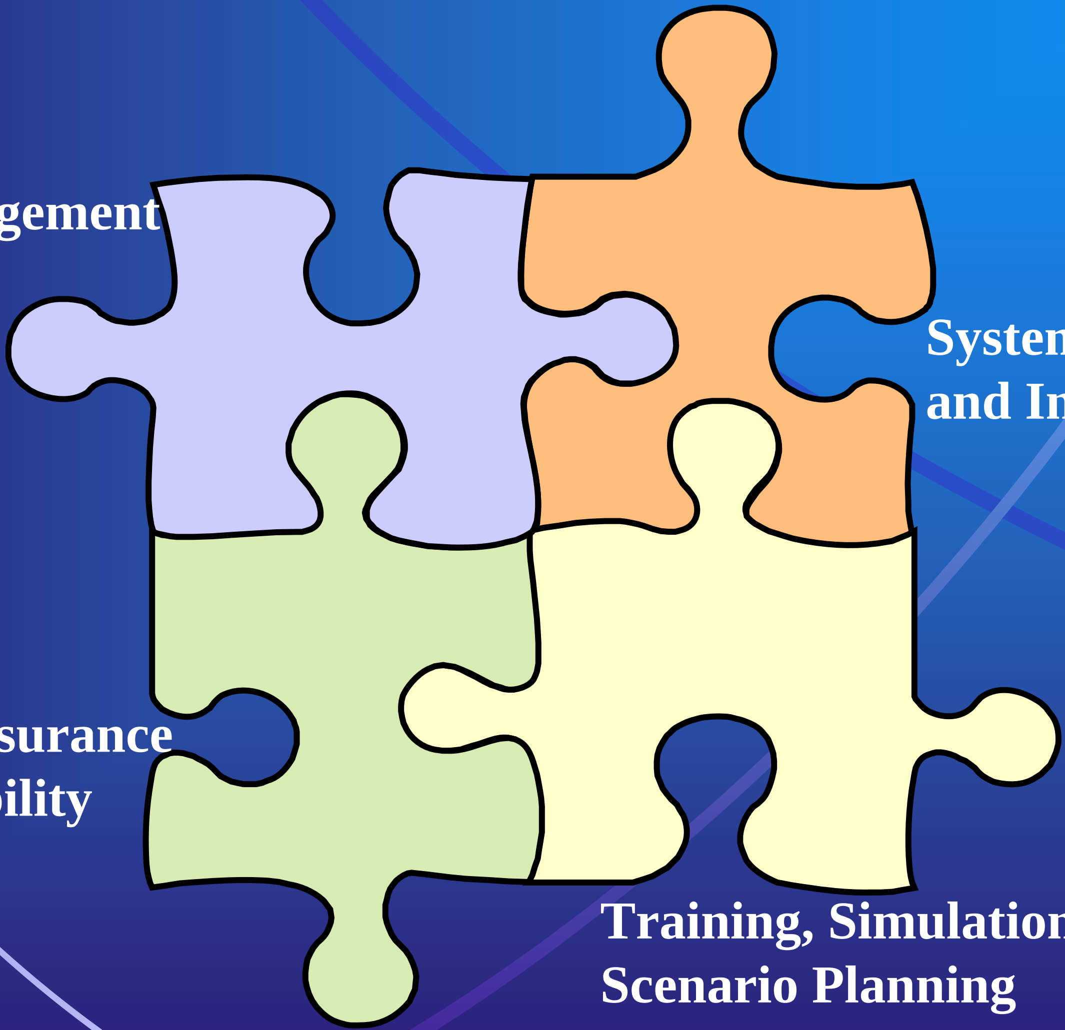
Management and Technical Services

- **Founded in July 1991**
- **Minority/veteran-owned**
- **Dedicated staff of experienced management and technical professionals**
- **Strategically located throughout the U.S.**
- **Solid history and past performance**

Energy Sector Support Areas

Disaster Management and Recovery

Systems Analysis and Integration



Energy Assurance and Reliability

Training, Simulation, and Scenario Planning

Briefing Outline

Use Data Systems to:

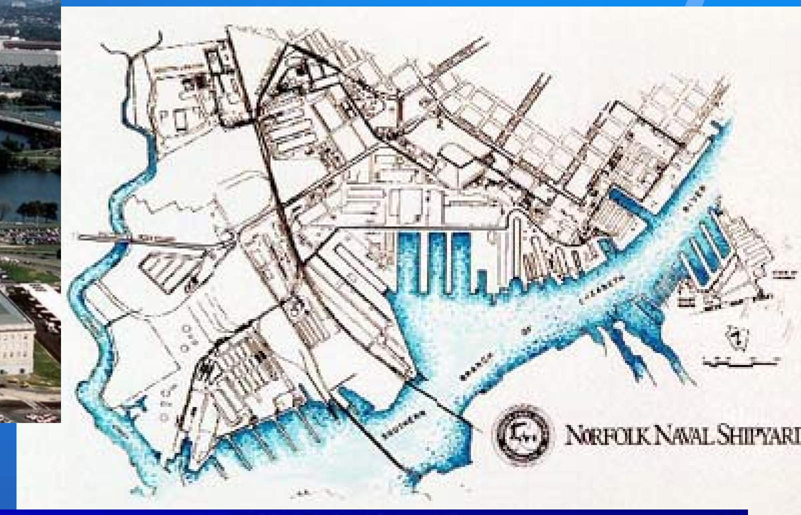
– Effectively manage power and energy systems

– Monitor and correlate power and energy availability and demand

– Optimize power and energy availability using alternative energy technologies

– Accrue Benefits for Enhanced Power and Energy

Energy Needs Differ



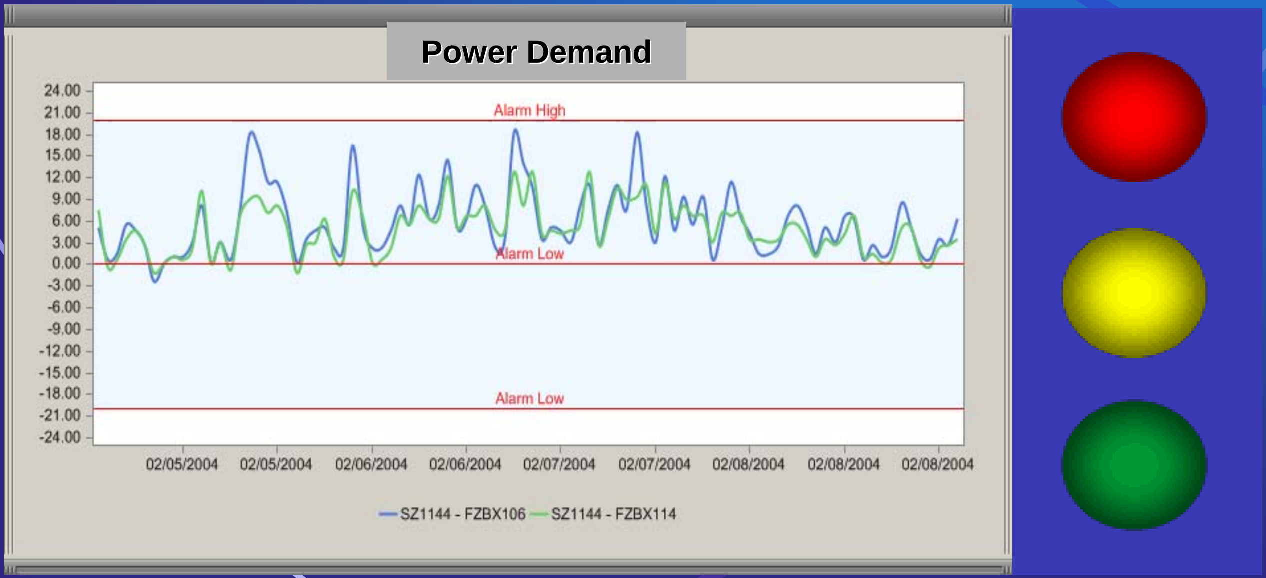
Energy Supply Differs

Energy Needs and Supply

- **Monitor generation**
- **Optimize**
  - fuel use
  - availability
  - reliability
  - risk
- **Correlate**
  - traditional (gensets)
  - alternative (fuel cell)
  - renewables (solar, wind, fuels)

Monitoring and Correlation

- Comprehensive Monitoring
- 24x7x365 Alert Notification



Source: Profile Systems, LLC

Monitoring and Correlation

Source: Profile Systems, Inc. / Purdue University - Calumet

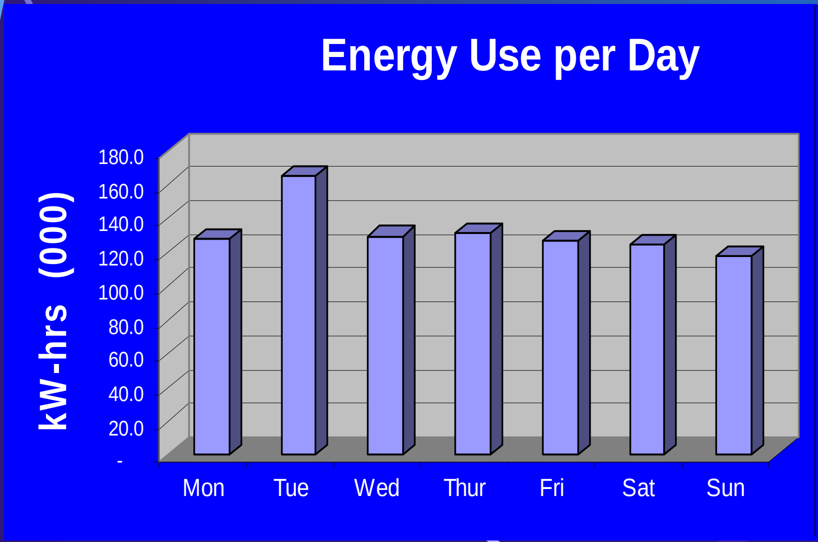
Monitoring and Correlation

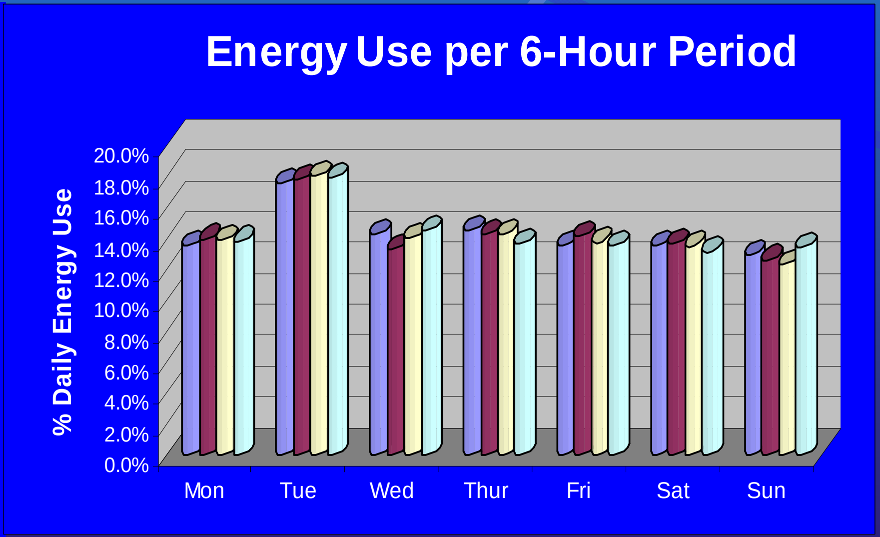
Energy Use per Day

	kW-hrs	% Tot	Cum %
Mon	127,587	13.8%	13.8%
Tue	164,746	17.9%	31.7%
Wed	129,599	14.1%	45.8%
Thur	131,054	14.2%	60.0%
Fri	126,926	13.8%	73.8%
Sat	124,347	13.5%	87.3%
Sun	117,381	12.7%	100.0%
Total	921,640	100.0%	100.0%

Energy Use per 6-Hour Period

12 - 6 am	6 - 12 am	12-6 pm	6 - 12 pm
13.6%	14.0%	13.9%	13.9%
17.6%	17.8%	18.1%	17.9%
14.3%	13.4%	14.1%	14.5%
14.5%	14.3%	14.3%	13.7%
13.6%	14.2%	13.7%	13.5%
13.6%	13.7%	13.5%	13.1%
12.9%	12.6%	12.4%	13.4%
100.0%	100.0%	100.0%	100.0%

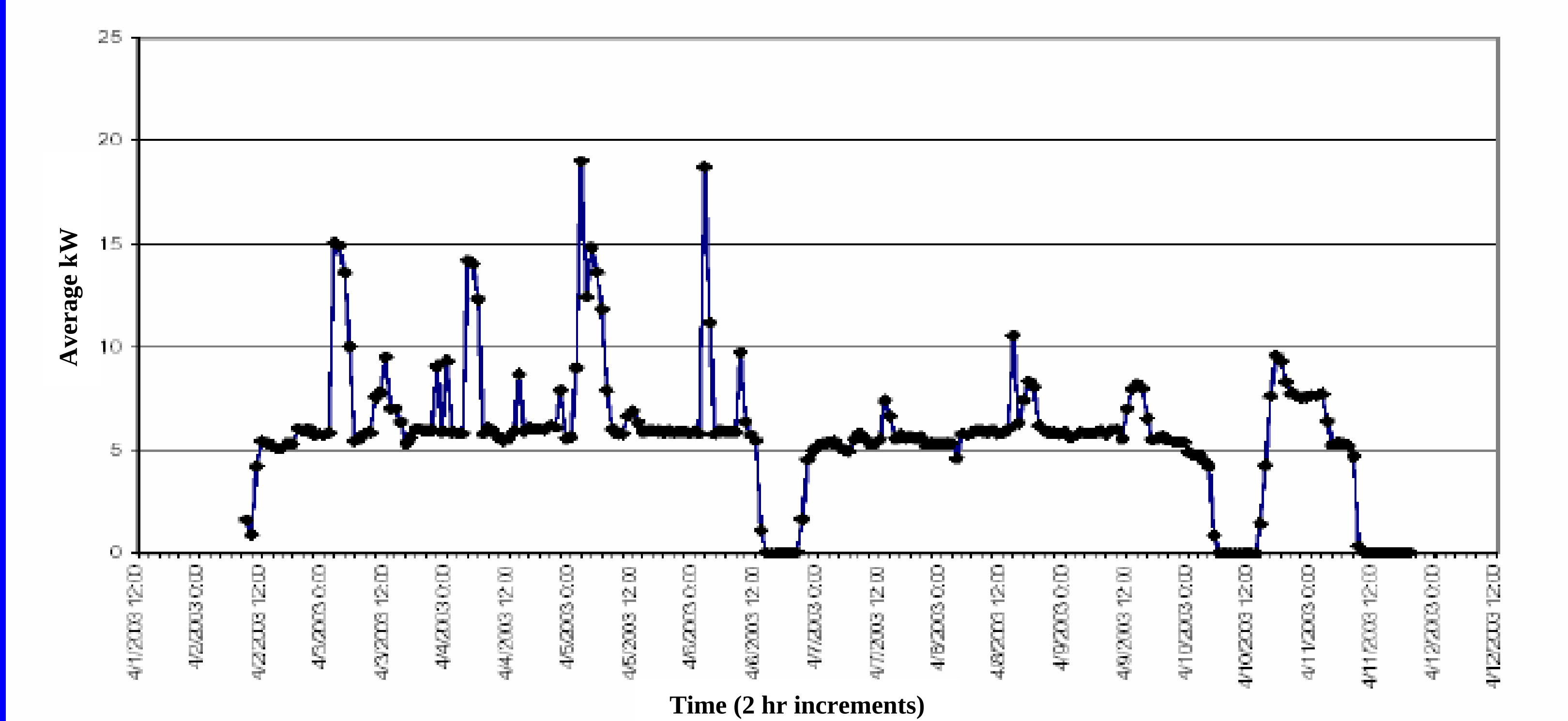




Source: U of Miami

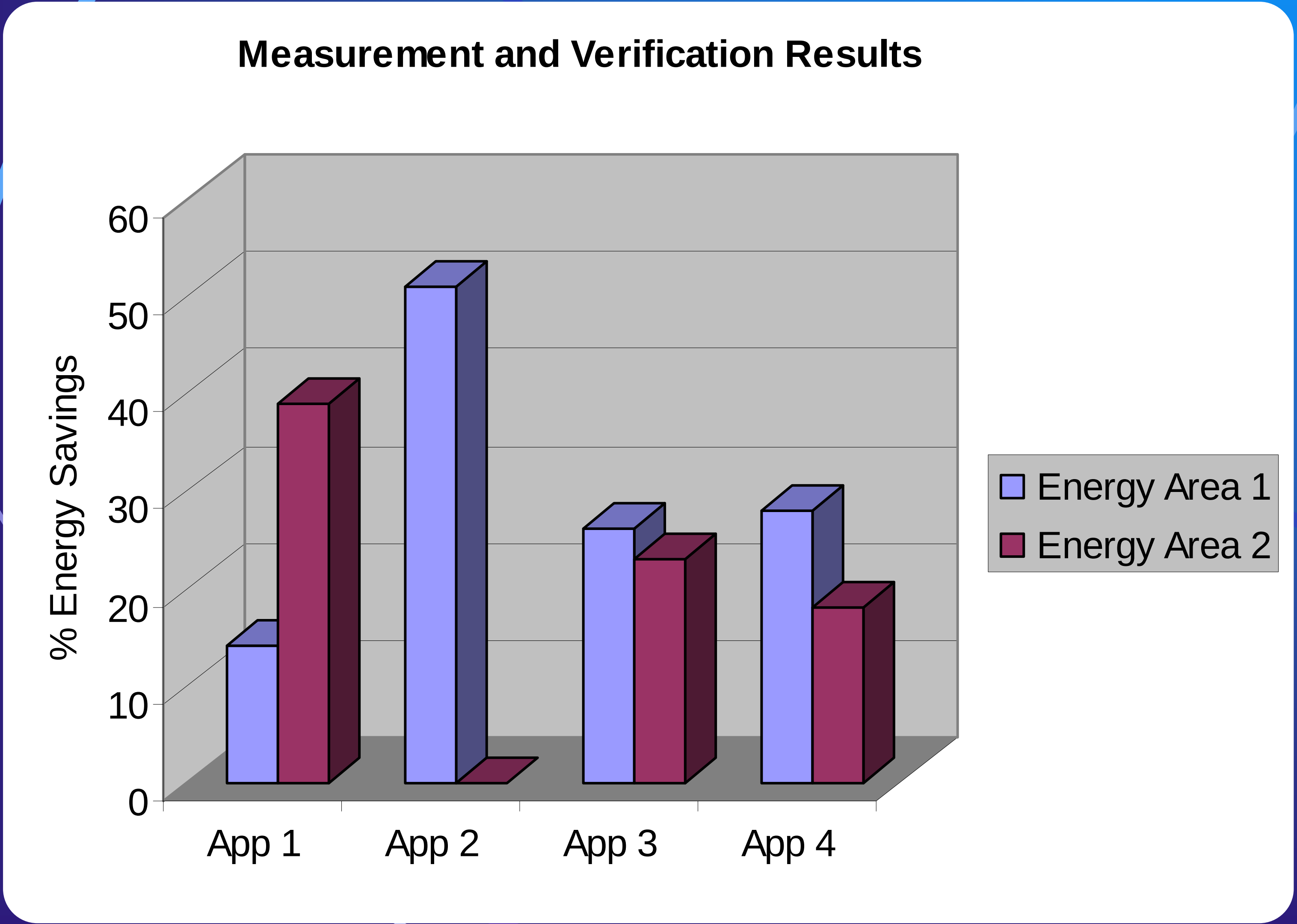
Monitoring and Correlation

Actual Tactical Operations Center (TOC) Load Profile



Source: CERL - ERDC

Benefits of Effective Power and Energy Management



Source: Profile Systems, LLC

Optimize Generation Alternatives

- Fuel storage
- Fuel availability
- ‘Local’ resources

Benefits of Effective Energy Data Management

- **Enhanced Awareness**
- **Improved Reliability / Assurance**
- **Improved Logistics**
- **Reduced Maintenance**
- **Archived Supply / Use Data**
  - Events
  - Trends
- **Reduced Costs**

Discussion

MTS Technologies, Inc.

Management & Technical Services

John W. "Jack" Adams

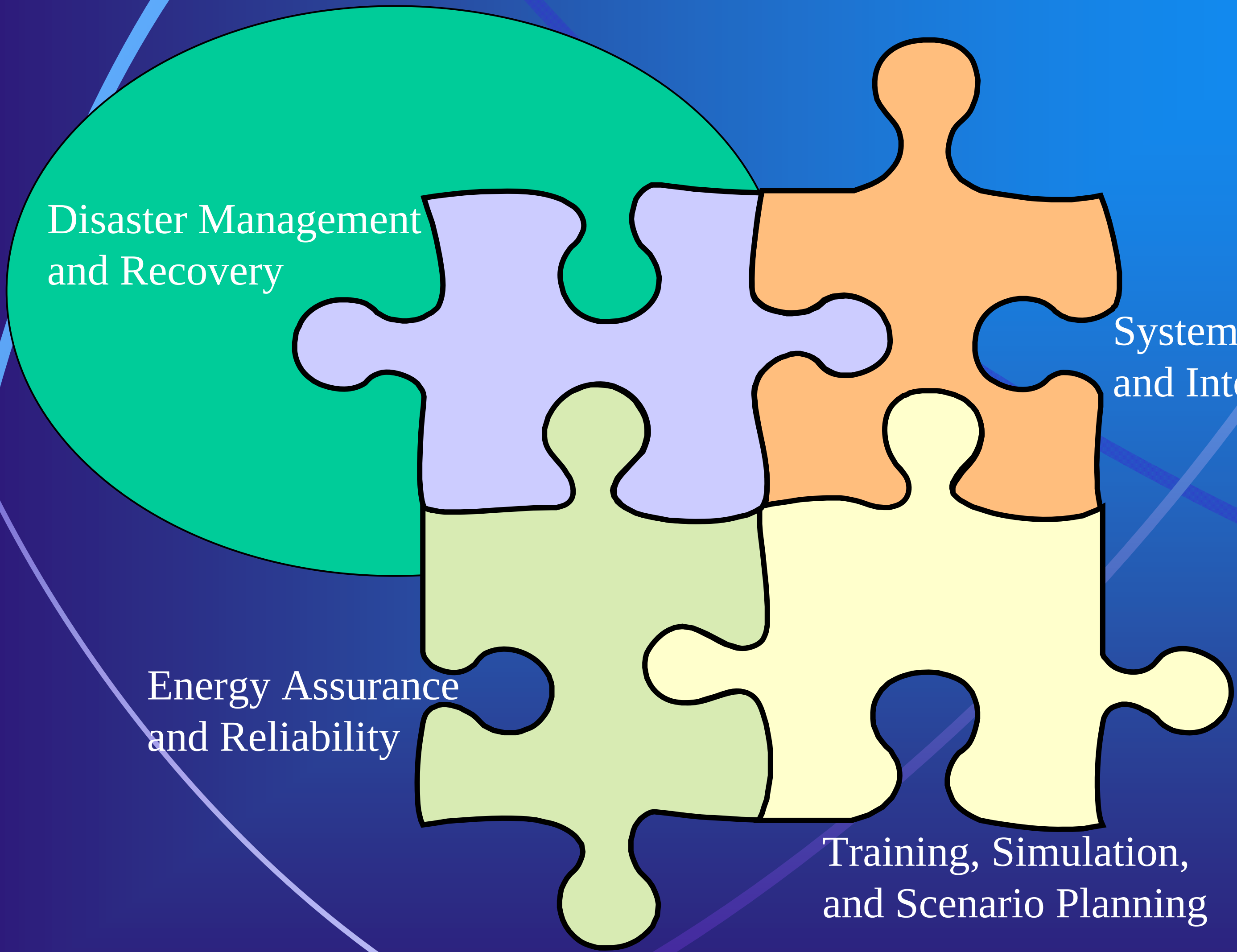
Energy Sector Consultant

2800 Shirlington Road
10th Floor
Arlington, VA 22206

724-327-4789
Fax: 412-291-3405
jackadams@adelphia.net

Back-up Slides

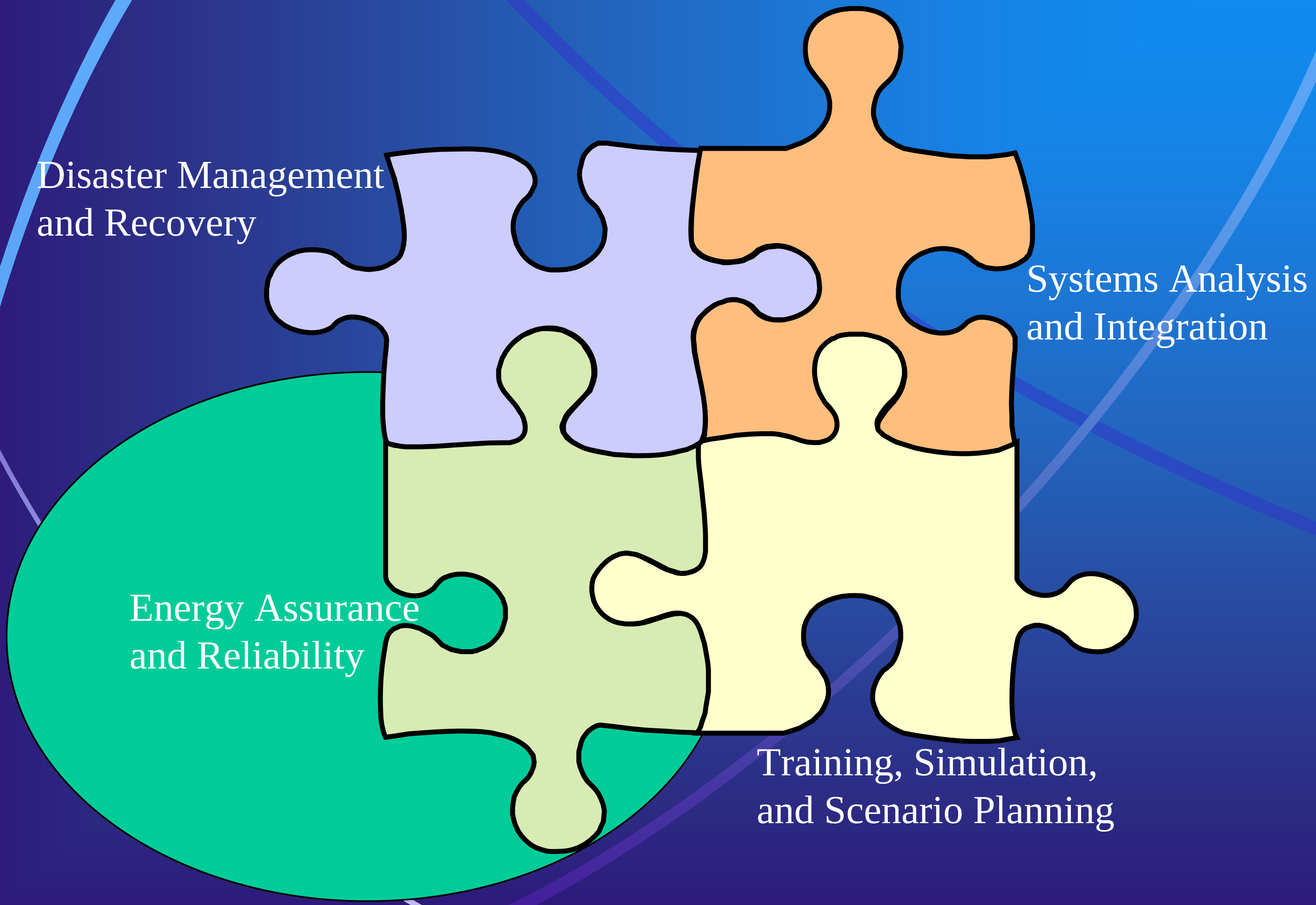
Energy Sector Support Areas



Disaster Management and Recovery

Provides Disaster Management Interoperability (DMI) - Services that allow government and non-governmental organizations to share data during the preparation, response, and recovery from disasters in a real-time environment as incidents unfold. *MTS* accelerated the deployment of this system by taking the product from concept to release. *MTS* provides functional and systems analysis; development, prototyping and testing; and field deployment. DMI-Services have been deployed nationwide and being used in several states. - Department of Homeland Security, Federal Emergency Management Agency (FEMA)

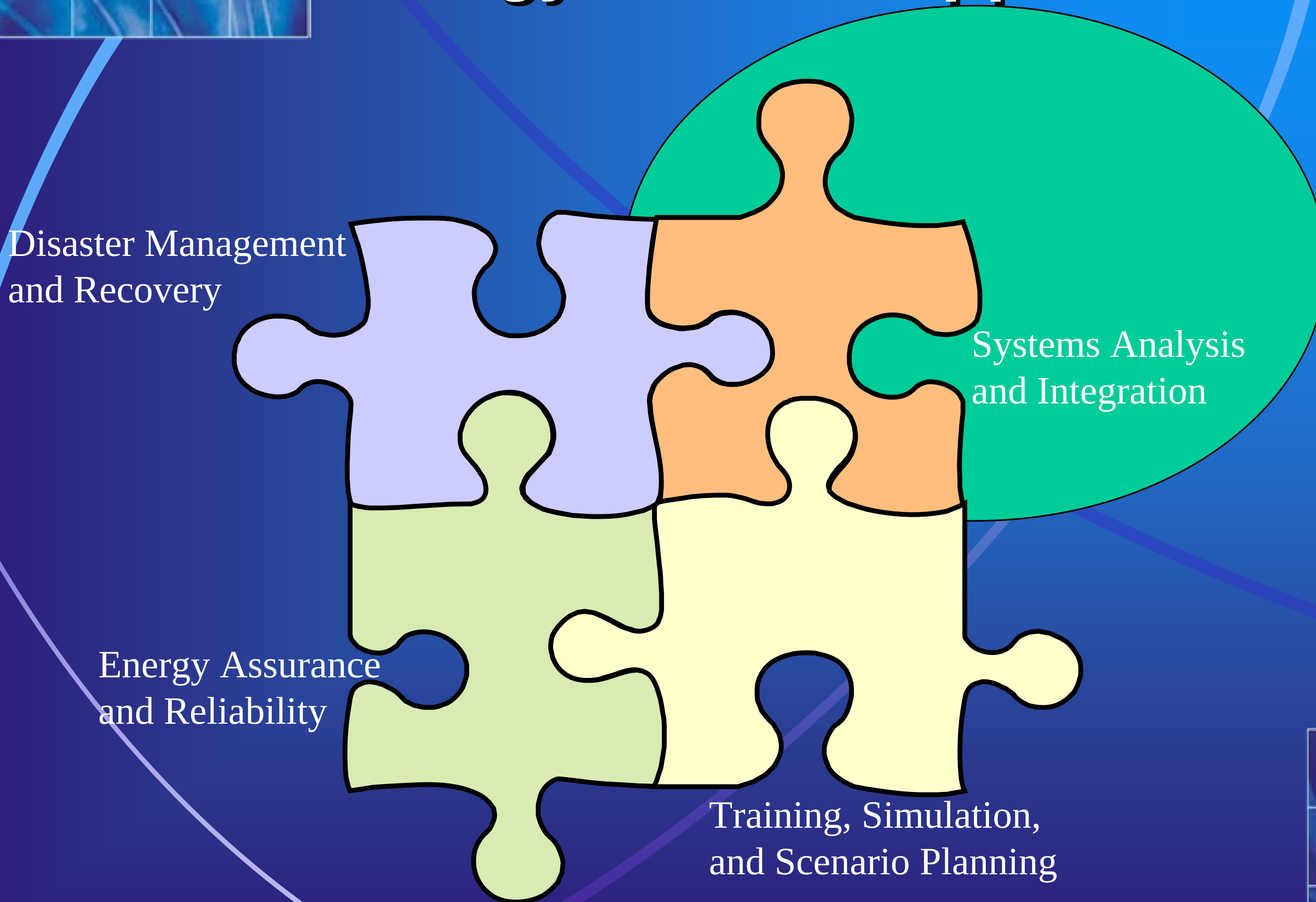
Energy Sector Support Areas



Interoperability provided through Electronic Architecture Integration to support the needs of the Future Combat System (FCS). The system also supports the efficient integration and interoperability of legacy systems. *MTS* develops and implements innovative systems that allow a commander to view location and operational/maintenance status of deployed systems; the ability to manage system software remotely; a first of a kind prognostic analyses program – U. S. Army TACOM, National Automotive Center

Provide Information Security for critical operations. *MTS* provides information assurance/information security support; prepares Blended System Security Authorization Agreements; prepares System Security Plan IAW DCID 6\3; conducts security testing and evaluation; provides security engineering for the component Integrated Product Teams (IPTs). - U. S. Marine Corps Presidential Helicopter Program with Lockheed Martin

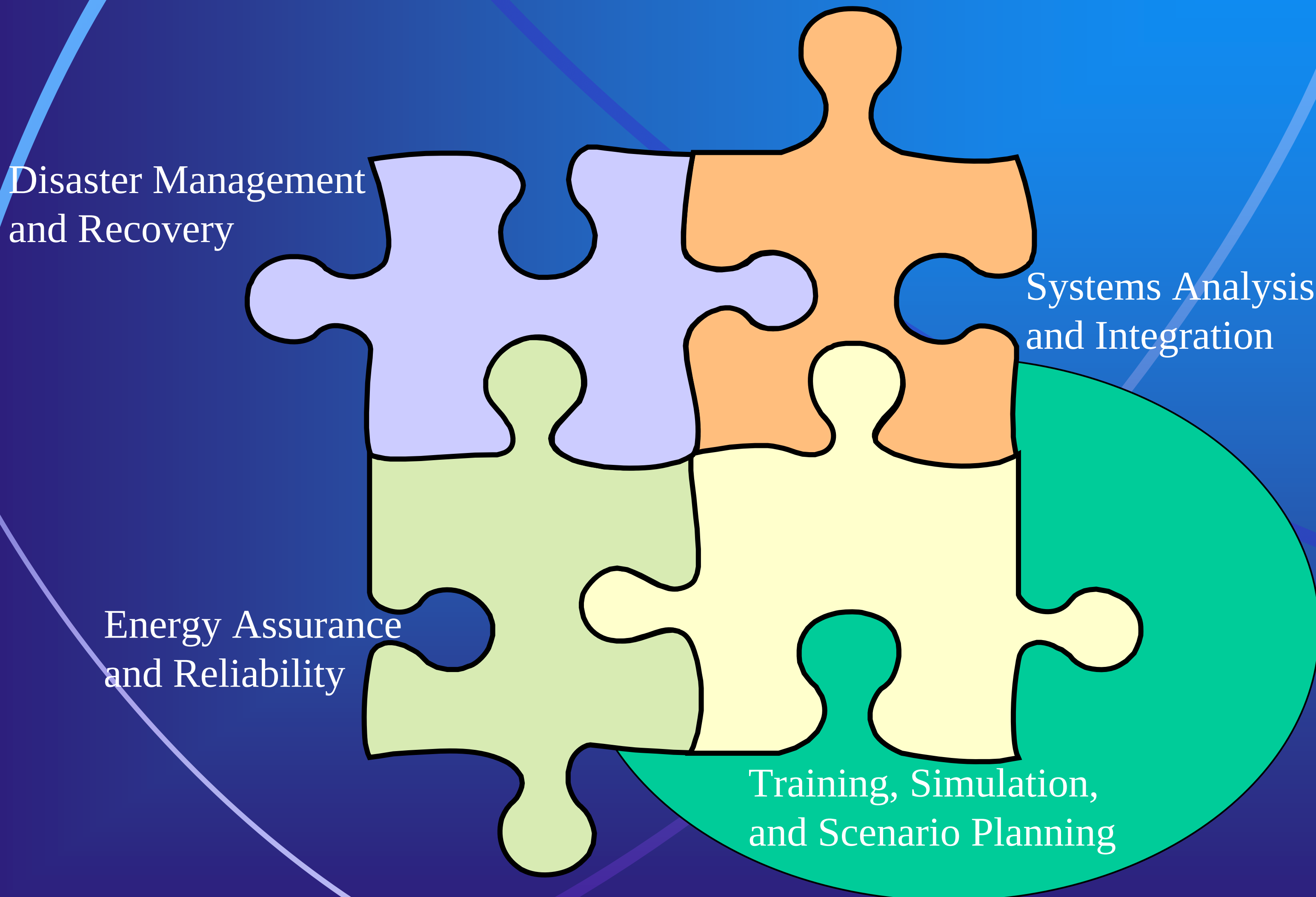
Energy Sector Support Areas



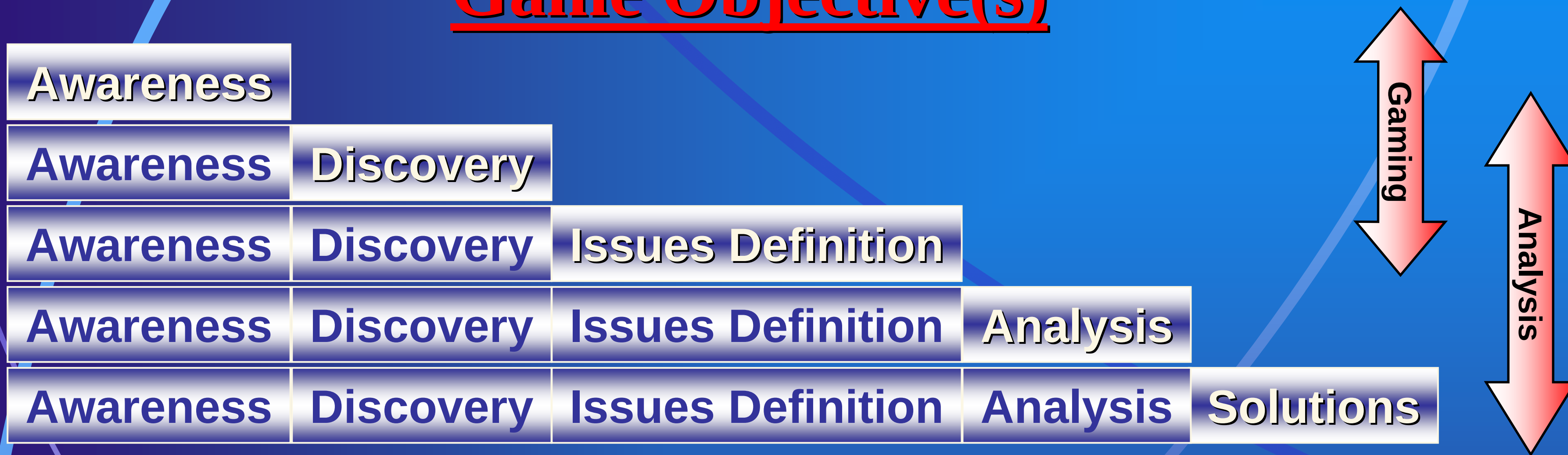
Conduct independent validation and verification of <u>technologies and strategies</u>. *MTS* compares the performance of alternative technologies to meet the stated objective and requirements; prepares integration strategies for viable technologies; develops deployment strategies for viable technologies and systems; helps to determine the suitable, essential and effective technology and strategy alternatives. *MTS* supports world-wide information and data collection initiatives using reliable and <u>secure technologies and systems</u>. – U. S. Navy, Naval Health Research Center

<u>Technical and Program Support</u> to subordinate Product Mangers to develop and procure conventional and leap-ahead products. *MTS* generates material requirements documents and conducts supporting analyses to enable transformation objectives; provides expertise in acquisition policy and program management; serves as subject matter experts in demolitions, engineer munitions, non-lethal systems, and mortars – U. S. Army PEO Ammunition

Energy Sector Support Areas



Game Objective(s)



- Games are specifically designed to focus on client's needs and concerns
- Games require pre- and post-game analysis
- Games can be combined with facilitated workshop to enhance:
  - –Analysis
  - –Issue resolution

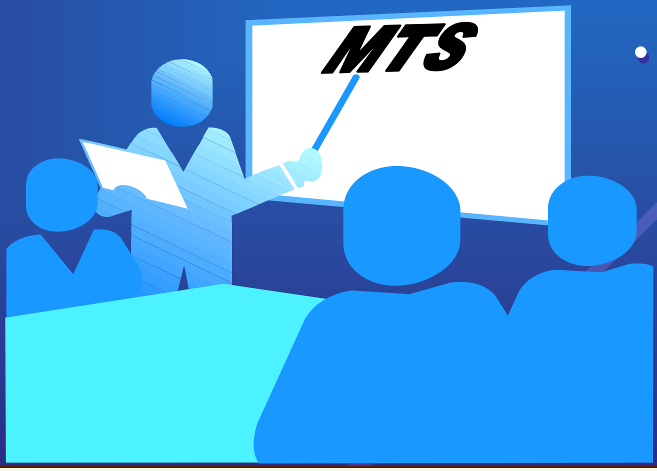
MTS Seminar Games

Classic seminar game

- Loosely structured
- Players fulfill most, or all, game input requirements:
  - Role players
  - Discussants
  - Threats
  - Controllers
  - Assessors

MTS seminar game

- **Systematic issue introduction**
- **Participants play themselves or their parent organizations**
- **Non-attribution policy**
- **Facilitators:**
  - Provide external inputs
  - Control game tempo & direction



Designed to ensure key issues come into play

Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications

Joint Services Expo, San Diego, CA
Apr 24-26, 2007

Shailesh A. Shah
Marketing Director, Military

Millennium Cell Inc.
One Industrial Way West
Eatontown, NJ 07724
shah@*millenniumcell.com*
732-542-4000

Who is Millennium Cell?

- The Hydrogen Battery Technology Company
  - Formed in 1998 and went public in 2000
  - Ticker symbol “MCEL”, NASDAQ market
- Hydrogen storage and passive PEM systems
  - **Chemical hydride expertise**
  - **Recently acquired Gecko Energy Technologies, a passive PEM fuel cell company**
  - Over 30 patents granted and 74 pending
- Focused on portable applications under 500 watts

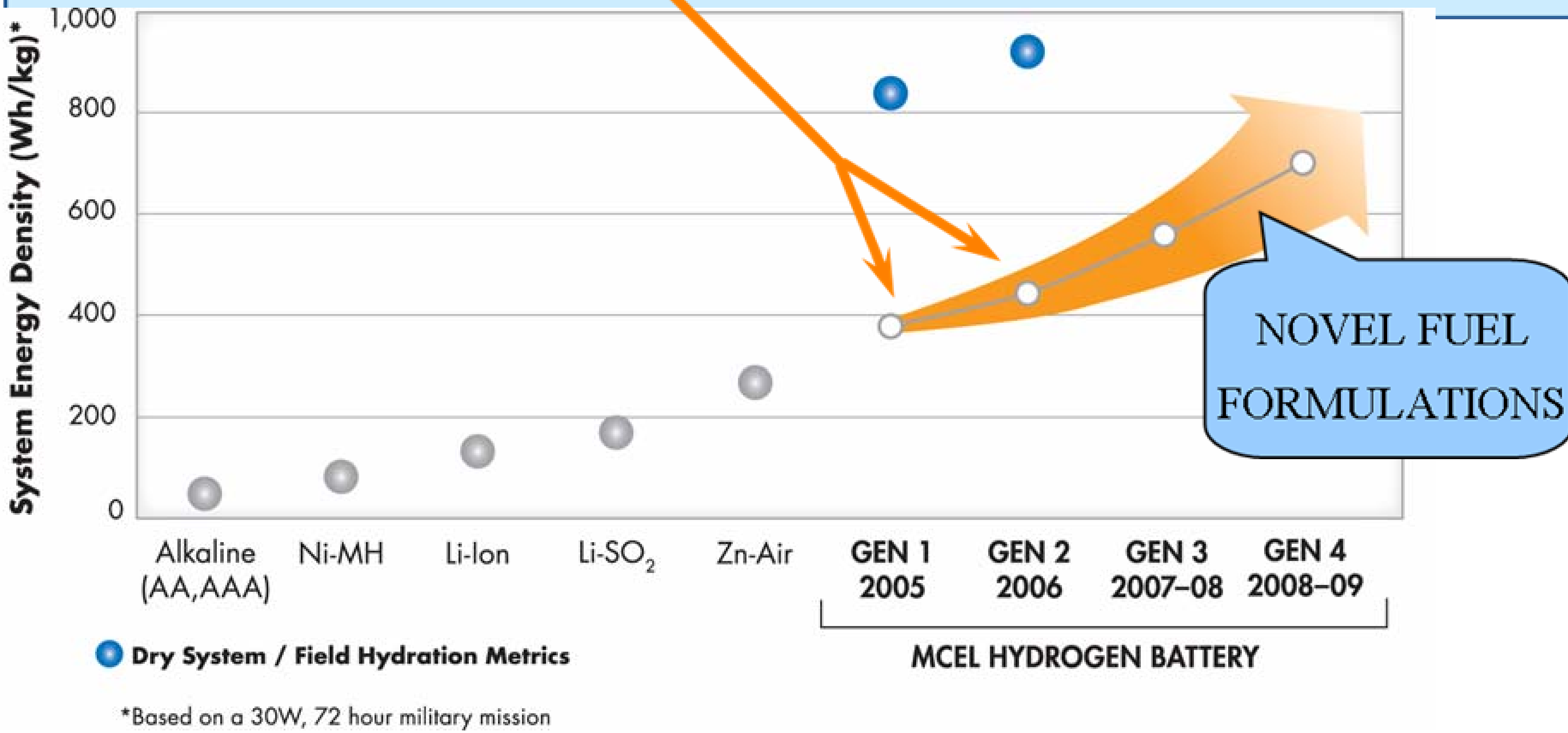
Strategic Relationships

- Collaboration to accelerate the commercialization of portable fuel cells
- Portable System Development
  - PEM fuel cell developers and licensees
  - Military development programs
  - Working with non-profit groups

Hydrogen Battery Technology
Hydrogen on Demand® Reaction

Millennium Cell
The Hydrogen Battery

$$\underbrace{NaBH_4\,(aq) + 4\,H_2O}_{\text{An energy-dense chemical hydride fuel}} \underbrace{\xrightarrow{cat}}_{\text{Rapid } H_2 \text{ production}} \underbrace{4\,H_2}_{\text{High purity hydrogen}} + \underbrace{NaB(OH)_4\,(aq)}_{\text{Borate can be recycled or disposed}} + \underbrace{heat}_{\text{No heat input}}$$



shah@ millenniumcell.com, (732)-544-5739, www.millenniumcell.com

Multiple Platforms for Military Applications

- **Sub 20 Watt Passive Platform**
  - Long run time wireless sensors
  - Rugged IT
- **20 – 100 Watt Platform**
  - Soldier Power
  - Military Radios
- **100 – 300 Watt Platform**
  - UAV, UGV
  - Battery Charging
  - Medical Evacuation
- **500 Watt Platform**
  - Critical Emergency Power
  - Remote Power

- **High Energy Density Fuel**
  - Less Weight
  - Less Volume
- **Safe**
- **Indefinite Shelf Life**
- **Fuel Gauge**
- **Hot Swappable Cartridge**
- **Silent Power**
- **Low Thermal Signature**

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Product Development

Passive platform for < 20 W applications

Millennium Cell
The Hydrogen Battery Technology Company

- Initial demonstration system
- Uses Gecko passive PEM fuel cell
  - High power density → fits in device
  - High efficiency → lower waste heat
  - Simple architecture with minimal BOP
  - Low cost → < $5 per watt
  - Thin, flat form factor → no extra volume
- Passive HOD™ system
- Target Applications:
  - wireless sensors,
  - handset chargers,
  - wearable power,
  - perimeter security

Night Vision Camera

First demonstrated in Sep 2006

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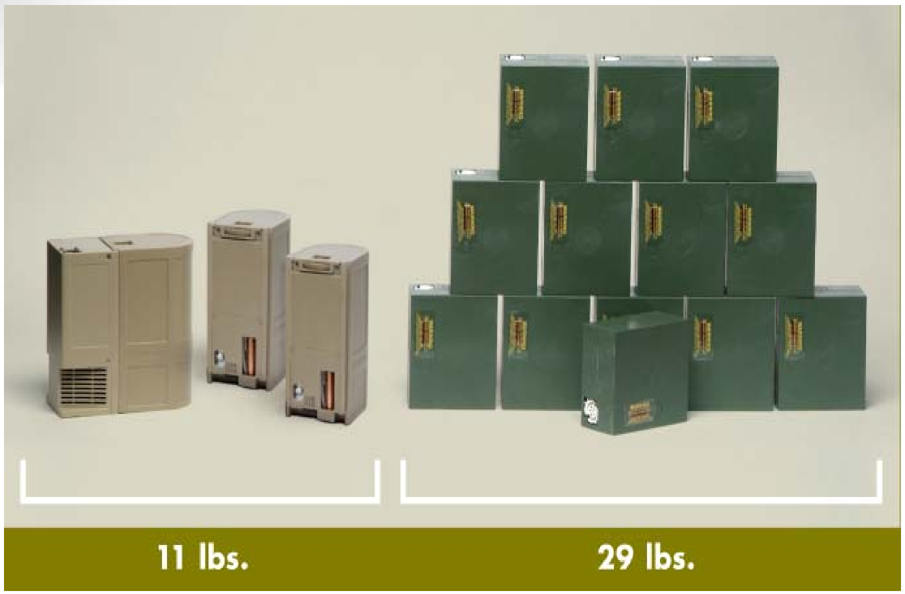
Product Development
Protonex + Millennium Cell

Millennium Cell
The Hydrogen Battery Technology Company

30W Soldier Power System



- 30 W x 72 hour mission
- 66 % Lighter than BA 5590
- 20 % Cheaper

150W UAV Power System

- Enables 4X – 6X Flight times

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Product Development
Jadoo + Millennium Cell

The Hydrogen Battery Technology Company

SOCOM PSC-5D Radio

- 55 W nominal power
- Fits in 2 x BA 5590 battery box

N-StorNB

eXtended Run Time

- 100 W Auxiliary Power
- 2200 Wh Energy
- 110 V, 12 V interface

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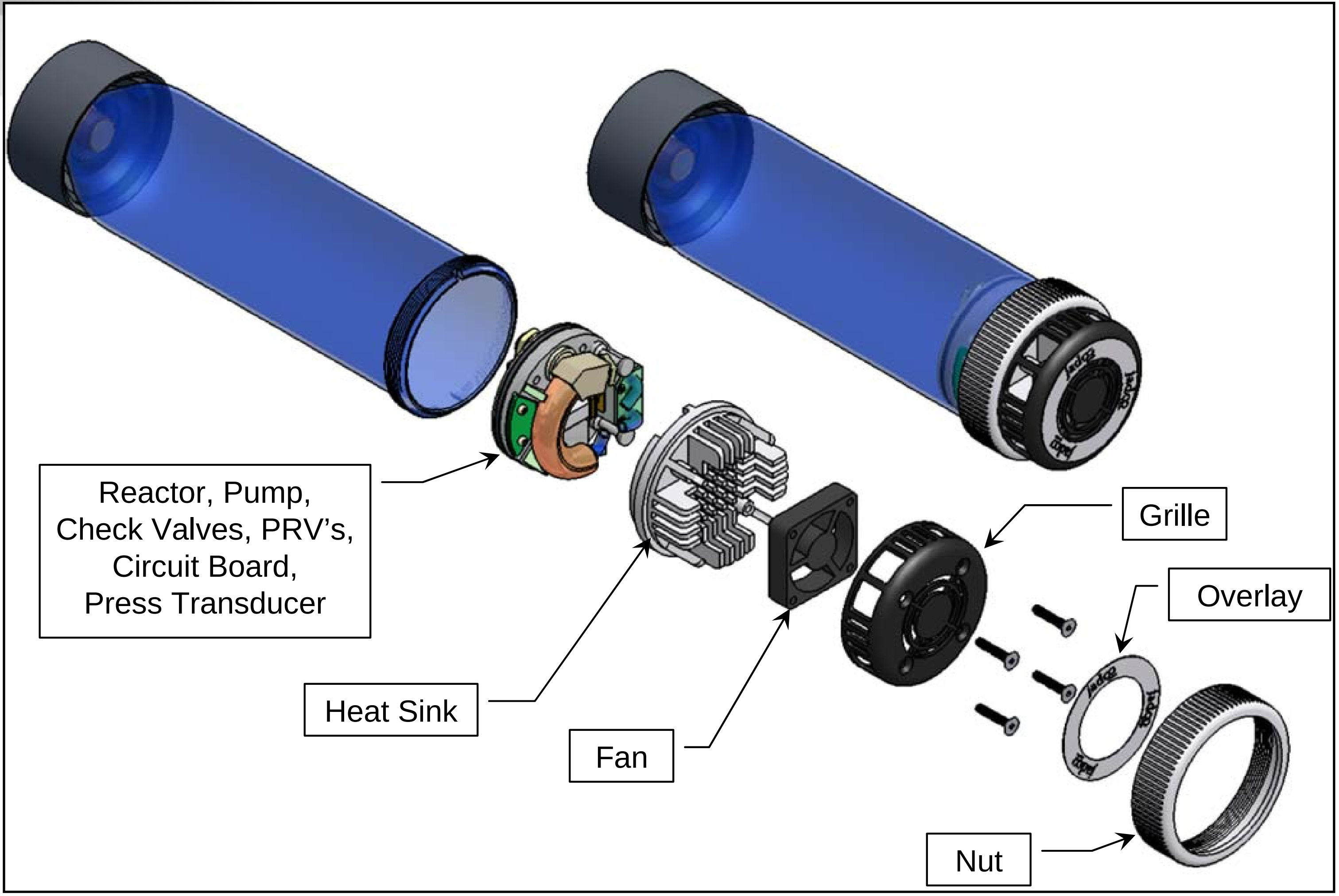
Cartridge Detail View
N-StorNB (NB: Sodium Borohydride)

Millennium Cell
The Hydrogen Battery Technology Company



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Value Proposition

Special Operations Radio

The Hydrogen Battery Technology Company

Based on 11 day mission	Jadoo & MCEL Fuel Cell System	BA-5590 Battery
Configuration for mission	1 Fuel Cell 7 x 500 W-hr Fuel Cartridges	35 Battery Packs
Weight of System	11 kg (24 lbs)	36 kg (79 lbs)

Status: First prototype demonstrated Sept. 2006
Delivery to SOCOM in Q2-07

Competitive Advantage: Field hydration, non-flammable fuel
66% lighter than BA5590

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Product Development

Cartridge manufacturing

Millennium Cell
The Hydrogen Battery Technology Company

- Development programs to establish manufacturing technologies for cartridge components
  - Catalyst material / reactors
  - Fuel / byproduct assemblies
  - Cartridge shell
  - BOP components (e.g., pumps, valves)

- Materials and processes scaleable to higher volume production
- Recently established in-house manufacturing capacity to support initial cartridge sampling
  - ~250 cartridges for evaluation in South Carolina in 2007-8

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Summary

- Significant Sodium borohydride ($NaBH_4$) expertise
- Novel Fuel Formulations offer higher energy density
- Portable systems being evaluated by military partners → Field Trials this year
- Technology development → product development / manufacturing
- Developing 3 – 5 Watt passive fuel cell systems

Thank you!

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USMC Family of Environmental Control Equipment

Major David C. Morris
Deputy Program Manager / Project Officer
david.c.morris@usmc.mil

AGENDA

- USMC Family of Environmental Control Units (ECUs)
- Issues with current ECU Family
- Future Family of ECUs
- Desired Improvements
- Technologies of Interest
- Field Refrigeration System/Refrigerated Boxes
- HVAC Tool Kit

FAMILY OF ECUs

- ¾ Ton (9,000 BTU/hr)
  - <u>In production verification testing</u>
- 1.5 Ton (18,000 BTU/hr) ECU
  - <u>Fielding</u>
- 3 Ton (36,000 BTU/hr) ECU
  - <u>Fielding</u>
- 5 Ton (60,000 BTU/hr) ECU
  - <u>Fielding</u>
- 8 Ton (96,000 BTU/hr)
  - <u>Developed and tested, but not fielded</u>

FAMILY OF ECUs

- USMC unique items
- 50/60 Hz
- R-22 Refrigerant
- Replaces multiple types of (vertical and horizontal) military standard units
- 3/4 Ton unit is single phase 120 VAC
- Larger units are three phase 208 VAC

ECU ISSUES

- **400 Hz ECUs**
  - The family of ECUs does not replace any 400 Hz ECUs.
  - The problem of supporting 400 Hz systems is a known issue.
  - We are developing an interim solution of refurbishing the fleet of 400 Hz ECUs to extend service life until the requirement disappears.
- **Family of ECUs interface issues**
  - The family of ECUs does not interface with some specific systems in the same way as the older ECUs.
  - The interfaces are being redesigned for replacement systems.
  - Interim solution is to retain existing ECUs for those limited applications.

FUTURE ECU FAMILY

- **A new family of ECUs will be developed to replace the current "family of" ECUs in the 2010-2012 time frame.**
- **New refrigerant**
  - **Will need to use a more environmentally friendly (and less regulated) refrigerant.**
  - **Next refrigerant is yet to be determined, but industry and the US Army seem to like R-410A.**
  - **For economy, we will follow industry as much as possible.**
  - **R-134A will see continued use in automotive systems and refrigeration systems.**
- **New family will probably have same ECU sizes, but largest unit may be 10 tons rather than 8 tons.**

DESIRED IMPROVEMENTS

1. Reduced power requirements
2. More ruggedization (for transport)
3. “Soft Start” to reduce startup power
4. Better energy efficiency
5. Reduced noise
6. Better heating capability
7. Multi-frequency and multi-voltage capability

TECHNOLOGIES OF INTEREST

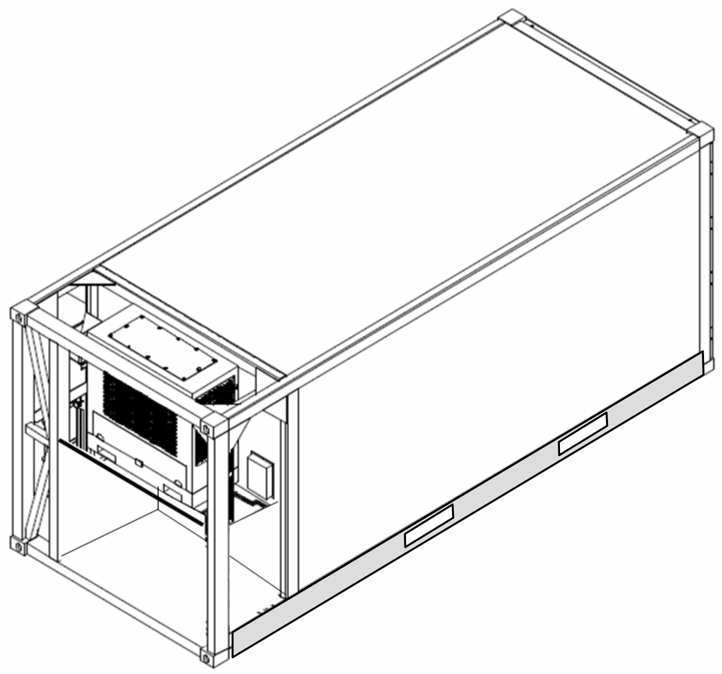
- **Variable speed drive for compressors**
- **Variable displacement compressors**
- **Multi-compressor systems**
- **Environmentally acceptable refrigerants**
- **Heat pumps**
- **Thermo-electric systems**
- **Fabric ducts**
- **Radiant spot heating**

FIELD REFRIGERATION SYSTEMS

- Large Field Refrigeration System (LFRS)
  - Based on standard 20-foot insulated ISO container
- Mortuary Affairs Refrigeration System (MARS)
  - Similar to LFRS, but with unique internal features
- Small Field Refrigeration System (SFRS)
  - Developed by Food Services
  - Based on Quadcon (quarter ISO) container
- "Legacy" 10-foot Refrigerated Boxes

LARGE
FIELD REFRIGERATION SYSTEM

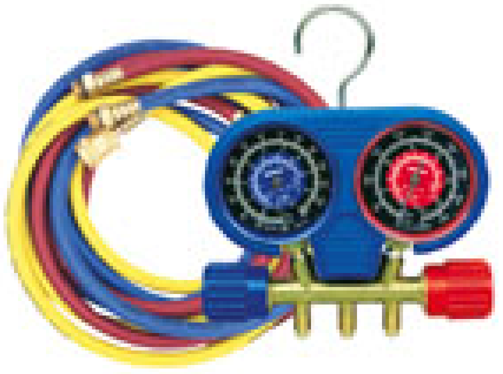
- **Large Field refrigeration System (LFRS)**
  - Based on standard 20-foot ISO container
  - Based on commercial equipment modified to meet military requirements
  - Single item for refrigeration unit and insulated box (no longer two separate items)
  - <u>Currently awaiting responses from vendors</u>



Food Services and Utilities support have landed !

FUTURE RECOVERY SYSTEM

- Will be included in new version of HVAC tool kit
- Replaces functionality of existing recovery machine in a more portable kit
- Advantages:
  - Portable
  - Light
  - No digital screen
  - Faster recovery
  - Oil-less compressor
  - Can be used with more refrigerant types
  - No filters to replace



Notional Solution Only

NEW HVAC TOOL KIT

Replacement for Refrigeration Tool Kit

- Replaces 2 existing items with one
- Modern refrigeration tools
- Updated hand tools
- Also replaces consumables kit that is currently a separate item
- <u>Currently awaiting responses from vendors</u>

Current System

Tool Kit, Refrigeration Service, Expendable Supplies

Recovery Machine

New HVAC Toolkit

Questions ?

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14

Integrated Trailer-ECU-Generator (ITEG)

Major David C. Morris
Deputy Program Manager / Project Officer
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WHY ARE WE HERE ?

Family of Generators
2 – 100 kW

Family of Trailers
HMMWV, MTVR, LVS

Family of ECUs
9K – 96K BTU/hr

But all three can not be mated and HMMWV towed

(with sufficient power and cooling capacity)

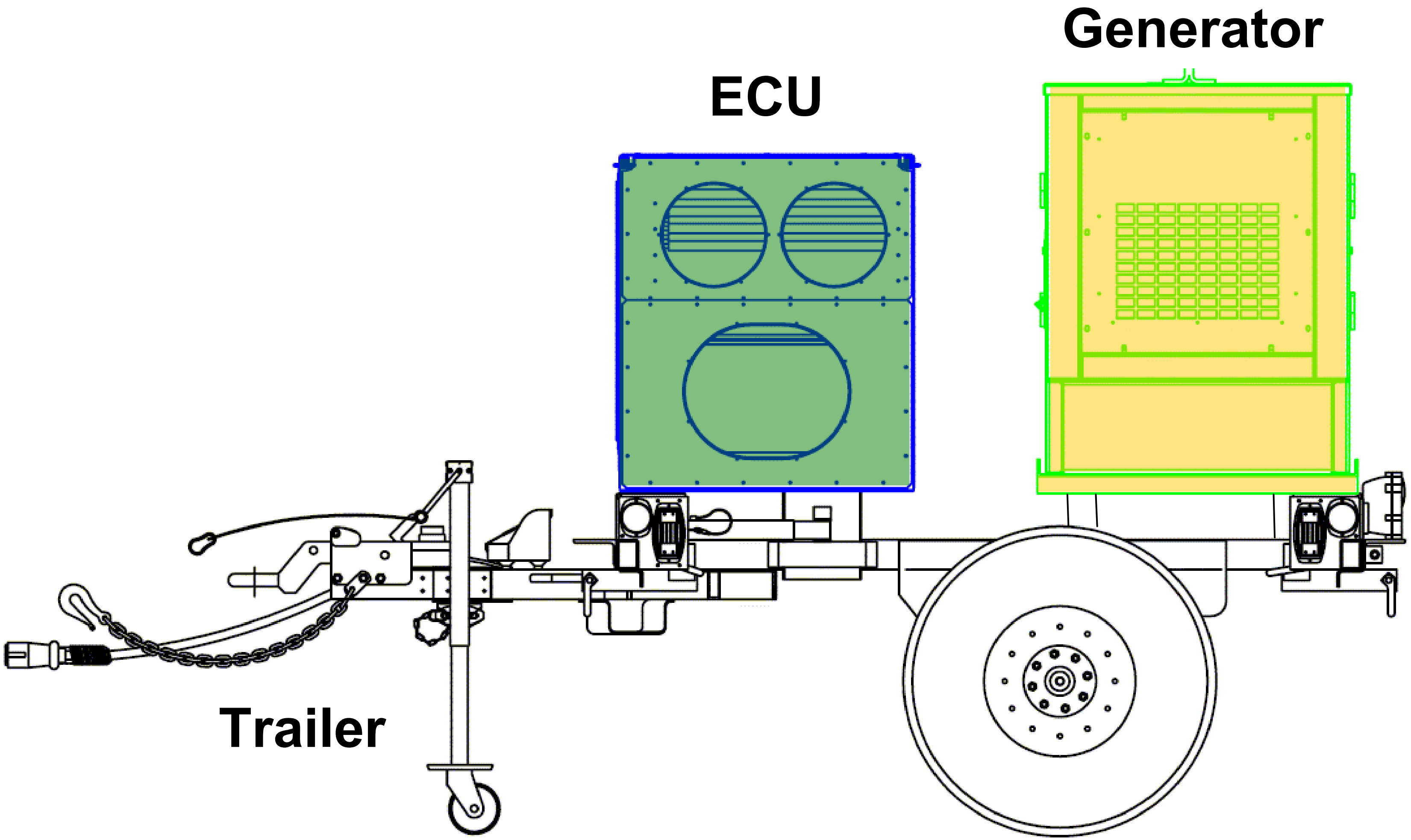
AGENDA

- ITEG Definition
- Requirement
- History of ITEG Development Efforts
- Current ITEG Effort
- ITEG Supportability
- Project Timeline
- ITEG Project Issues
- Future ITEG development
- Questions

ITEG DEFINITION

- Integrated Trailer-ECU-Generator (ITEG), also known as Generator-ECU-Trailer (GET)
- System that combines a diesel electric generator and Environmental Control Unit (ECU) on a HMMWV-towable trailer
- Usually includes requirement for additional cargo capacity to carry a tent on the trailer
- General requirements
  - Mobility: 4200 lbs or less gross weight & HMMWV towable
  - Power available: 10 kW or more with max ECU demand
  - ECU: 8 tons/96,000 BTU per hour cooling and 40,000 BTU per hr heating

ITEG DEFINITION



USMC ITEG REQUIREMENT

- **4 Universal Needs Statements (UNS) have come into MCCDC for ITEG systems**
  - **2 Urgent, 2 Conventional**
  - **Currently being validated via Combat Development Process**
- **An ITEG variant (General Dynamics GET Spiral 1) is currently part of the Combat Operations Center (COC) program.**
- **Various other commercial ITEGs have been purchased by Marine Corps units for other purposes.**

ITEG DEVELOPMENT EFFORTS

- **Efforts began in 2005**
  - **Model development and analysis**
  - **Identification of three primary courses of action**
    - **Commercial off-the-shelf (COTS) or Modified COTS item**
    - **Integration of existing USMC components**
    - **Developmental system**
- **Based on business case analysis and user community input, the integration approach was selected (77% user preference).**

ITEG DEVELOPMENT EFFORTS

User community ranking of ITEG attributes:

1. Performance
   – Generator (export power availability)
   – ECU (cooling capacity)
   – Trailer (mobility)
2. Maintainability
3. Supportability
4. Transportability
5. System safety and human factors engineering

ITEG COURSES OF ACTION

1. **Do nothing – status quo**
   – Disparate & varied equipment in the fleet
   – Throw-away systems
   – No organic support
2. **Integrate existing USMC / Army supported products into system**
   – All built for general purpose, not specific use
   – Individually optimized for HMMWV transport, not in unison
3. **Procure COTS / NDI**
   – Least up-front cost
   – Adequate market to select from
   – Fleet acceptance of products
4. **Modify COTS / NDI**
   – Could possibly garner another 5-10% improvement
   – <u>Requires time and money</u>
5. **Developmental System**
   – <u>Requires lots of time and money</u>
   – Some long range efforts are underway (USMC SBIR, Army R&D)

COA 2 - INTEGRATE EXISTING COMPONENTS

- **Integration effort attempted with:**
  - **M-1102 HC trailer (HMMWV)**
  - **B0980Generator (MAGNUM 22 kW)**
  - **B0014 ECU (96,000 BTU/hr)**

- **Failed safety assessment due to excessive weight**
- **Will re-investigate in 2008 with new MTVR trailer (8000# payload)**

CURRENT ITEG PROJECT

- **With no funding available for a research and development program,**

- **The only remaining Course of Action was to acquire a COTS/NDI system (COA #3)**

CURRENT ITEG PROJECT

- **Market research performed in 2006 for:**
  - **HMMWV towable**
  - **96K BTU/hr cooling**
  - **20-30 kW total electrical power**
  - **300-500 lbs additional payload capacity**
- **Competition of responding vendors with commercial systems was held in 2006**
- **Program funded by the Defense Acquisition Challenge Program (OSD)**

CURRENT ITEG PROJECT

- **GD C4S Generator-ECU-Trailer (GET) selected**
  - Loaded Weight ≤ 4200 lbs
  - HMMWV towable
  - Payload Available ~ 290 lbs
  - Generator Capacity 20 kW
  - Export approx. 5-7 kW (with full ECU load)
  - Cooling Capacity 96,000 BTU/Hr *
  - Meets Environmental Performance requirements
  - Fuel Capacity 8 hrs
  - Uses modified LTT chassis

Currently in production verification testing

ITEG SUPPORTABILITY

- The General Dynamics (GD C4S) GET system is the Marine Corps standard for ITEG.
- ITEG will be organically supported
  - Parts support will be through the supply system
  - Maintainers will be trained to repair the ITEG
- ITEGs will be centrally controlled items
- Intent of this effort is to get the USMC to a single product
  - Programs / FMF units with other solutions will be on their own for support.
  - Even though we have a standard solution, the losers are still marketing their wares. "Caveat emptor" to the Fleet.

PROJECT TIMELINE

• **Proposals & Bid Samples Received**	**1 Jun 2006**
• **Aberdeen Testing (with User Evaluation)**	**Jun-Aug 2006**
• **Select/Award Single Winner**	**Sept 2006**
• **Deliver 5 systems for First Article Test**	**Dec 2006**
• **Conduct Production Verification Test**	**Dec 2006** to **May 2007**
• **Production Articles available**	**late 2007**

ITEG ISSUES

- ITEG is not a direct replacement for any current equipment item.
- PM EPS will provide the mechanism (contract) for other programs to obtain ITEGs as components of their systems
- There is no plan to field to using units as a stand-alone capability unless validated by MCCDC
- We have a contract limit of 200 units for the current contract

ISSUES

- **ITEGs are not the answer to every need**
  - **Standard generators and ECUs are more capable; many performance compromises were required to achieve HMMWV towability.**
  - **Not everything needs to be HMMWV towable.**

FUTURE DEVELOPMENT

- As long as the HMMWV is the tow vehicle, system weight is limited to ≤ 4200 lbs.
- Environmental regulations
  - Force change of refrigerants in ECU (2010)
  - Force change of generator engines (2008)
- More integrated generator/ECU
- Ability to manage and control ECU power requirements while preserving export power and the best possible level of cooling

Questions ?

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http://www.marcorsyscom.usmc.mil/sites/pmeps/default.asp

Joint Services Power Expo
April 24-26, 2007

“Solving power supply obsolescence, reliability, and power density issues by advances in power electronics technology”

Rich Sidley

Custom Manufacturing & Engineering

CUSTOM MANUFACTURING & ENGINEERING, INC.

A Power & Sensors Company

- **Integrated Power Supplies, Power Distribution & Management Products**
- **Remote Sensors & Monitoring Networks**
- **Obsolescence Solutions**

Problems

- 1995 DOD policy change allows military to integrate COTS into weapon systems.
  - COTS ≠ Military requirements.
  - Peak availability and lowest pricing of a given component may last only six to 18 months.
- Higher power densities → higher switching frequencies.
  - More RFI/EMI but can be handled by smaller components.
  - Layout (resonance).

COTS ≠ Military

- Special technical requirements for military power supplies fall into three main categories:
  - Environmental:
    - High temp:
      - Semiconductor MTBF halves for every 10 °C increase in operating temperature.
    - Low temp:
      - LCDs.
      - Capacitor dielectric.
      - Crystallization of potting compounds.
    - Shock and vibration resistance.
    - Dust.
    - Moisture.

COTS ≠ Military

- The special technical requirements for military power supplies fall into three main categories:
  - Input and output voltage:
    - Military specifications are stringent for low and high line conditions and voltage spikes, surges and excessive input ripple.
    - Output voltages are often non-standard when compared with commercial products.

COTS $\neq$ Military

- The special technical requirements for military power supplies fall into three main categories:
  - Electro-magnetic compatibility:
    - COTS does not necessarily pass any EMI standards
    - Military limits typically 10 Hz to 1 GHz, adding a range of conducted and radiated susceptibility and emissions requirements.
    - FCC and Europe’s EN55022 are lower bandwidth, etc.

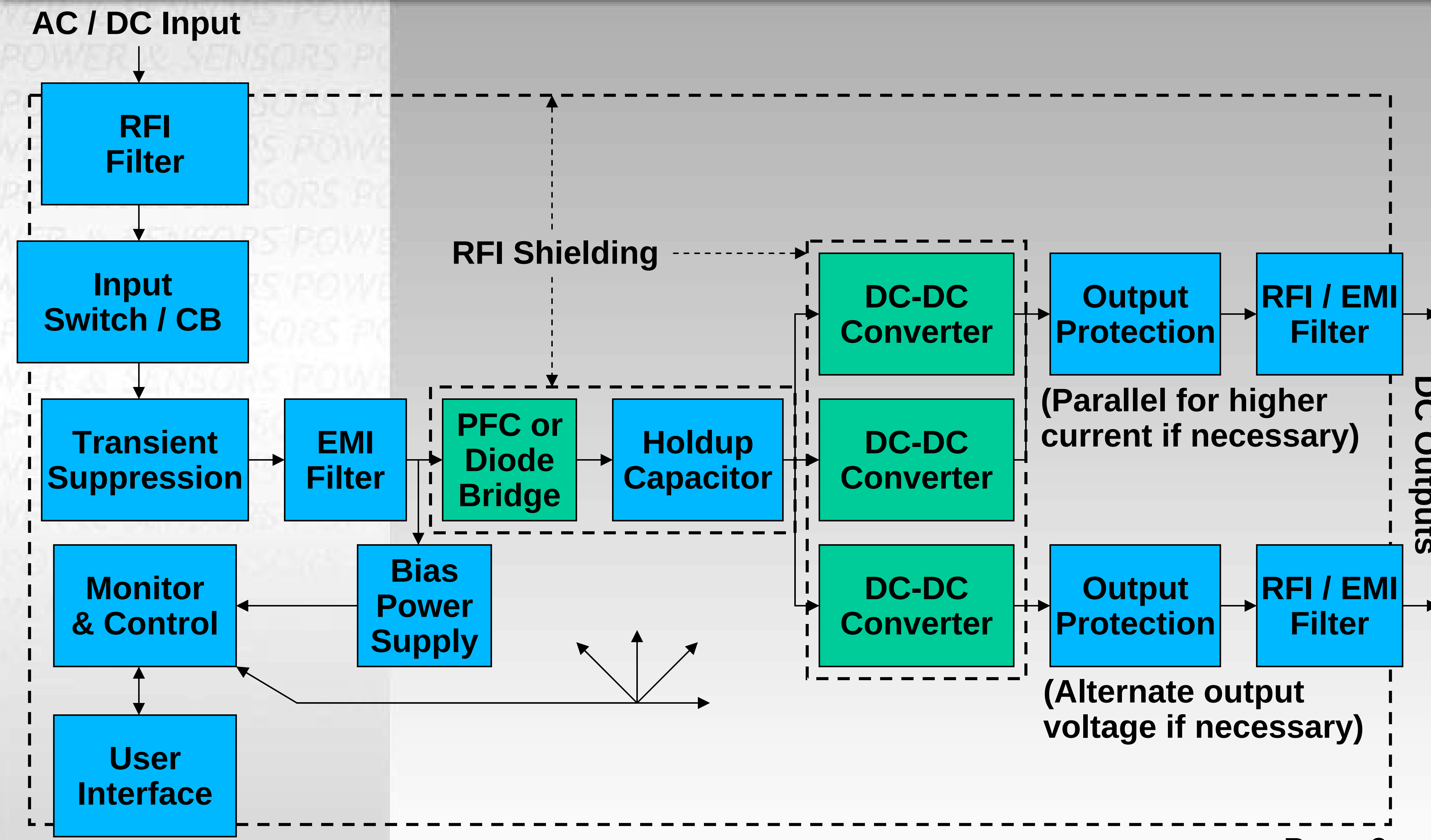
COTS $\neq$ Military

- Additional glue components:
  - Input and output conditioning are needed to achieve compliance.
  - Active filters remove spikes and filter both conducted emissions and conducted susceptibility such as transients or input ripple appearing at the output.
  - Radiated emissions are dealt with by complete screening of the final power supply.
- Considerable certification testing.

Military COTS

- Some components are called “Military COTS” but still are not self-sufficient to meet all military and system requirements.

CME's Generic Military Power Supply

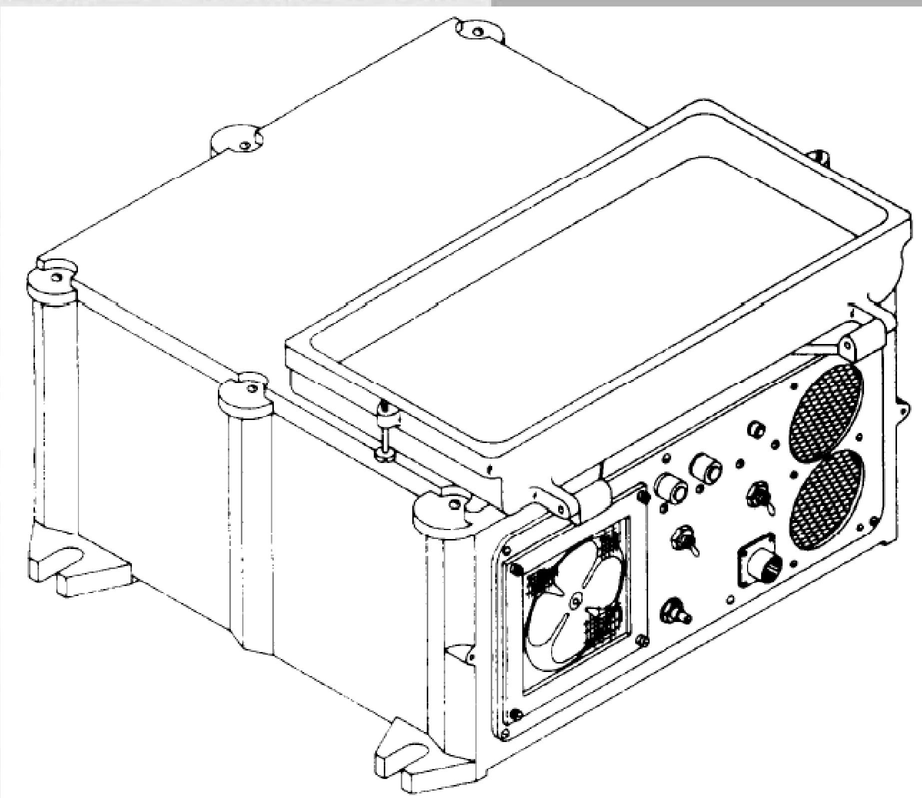


CECOM Tactical Power Supply W15P7T-04-R-C006

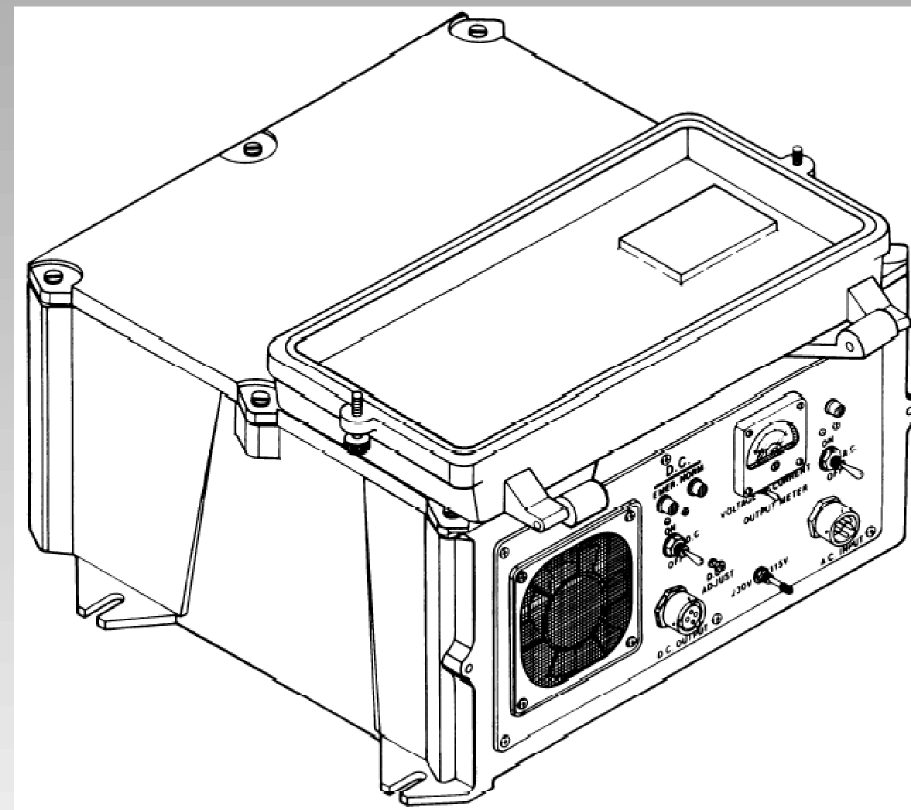
- Solicitation:
  - "The Army is seeking alternative designs for the cover used to protect the front panel assembly. Currently, the cover is attached to the housing assembly using steel spring pins and hinges. In a tactical environment, these pins break easily."
  - Combining two similar power supplies:
    - PP-2953C/U
    - PP-6224B/U

    into one via MIL-PRF-49080B (CR).

Two Obsolete Power Supplies

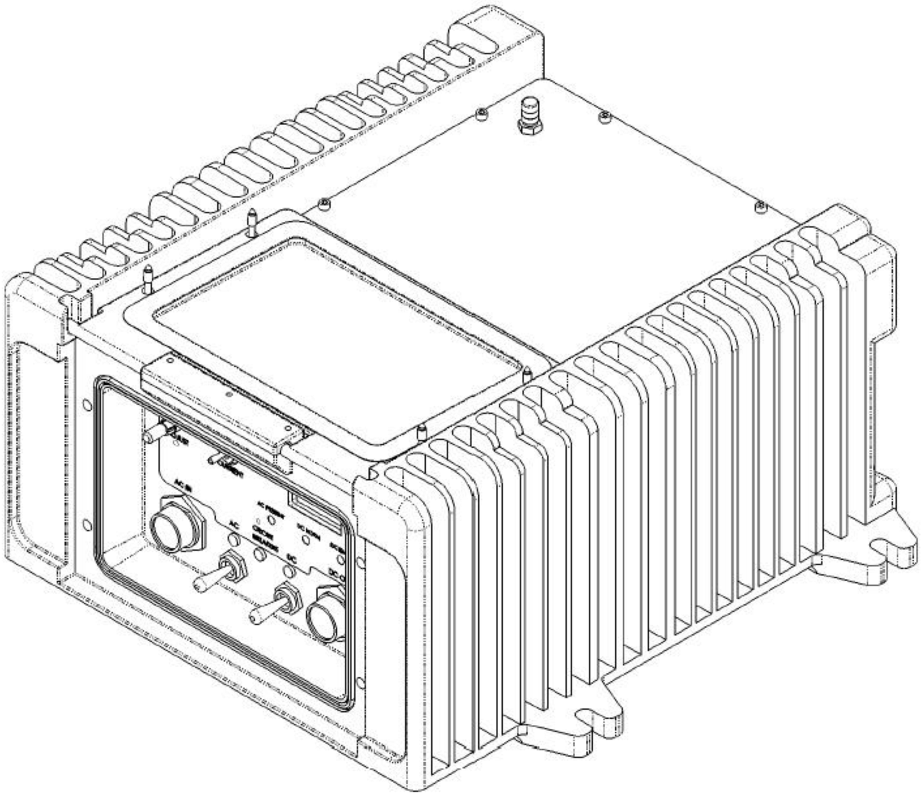


PP-2953C/U



PP-6224B/U

Combined Replacement Power Supply



PARAMETER	CHARACTERISTIC
Power Input	115/230 VAC, 50, 60, or 400 Hz, Single Phase (Automatic input power detection)
Power Output	Adjustable 24 – 32 VDC at 0 to 25A (800W)
Standby Mode	24 VDC Battery Standby Mode (pass-through, not DC-to-DC) adjustable from external battery
Output Stability	+/- 1% peak, 0.5% RMS max ripple from 20 Hz to 10 MHz
Temperature Operating Range	Ambient temperatures in the range of 150° F (+66°C) to -40°F (-40°C)
Efficiency	Greater than 70%
Height	7.0 Inches
Width	14.25 Inches
Depth	14.5 Inches
Volume	1446 Inches^3 (0.55W per Inch^3)
Weight	36 Pounds (22W per pound)

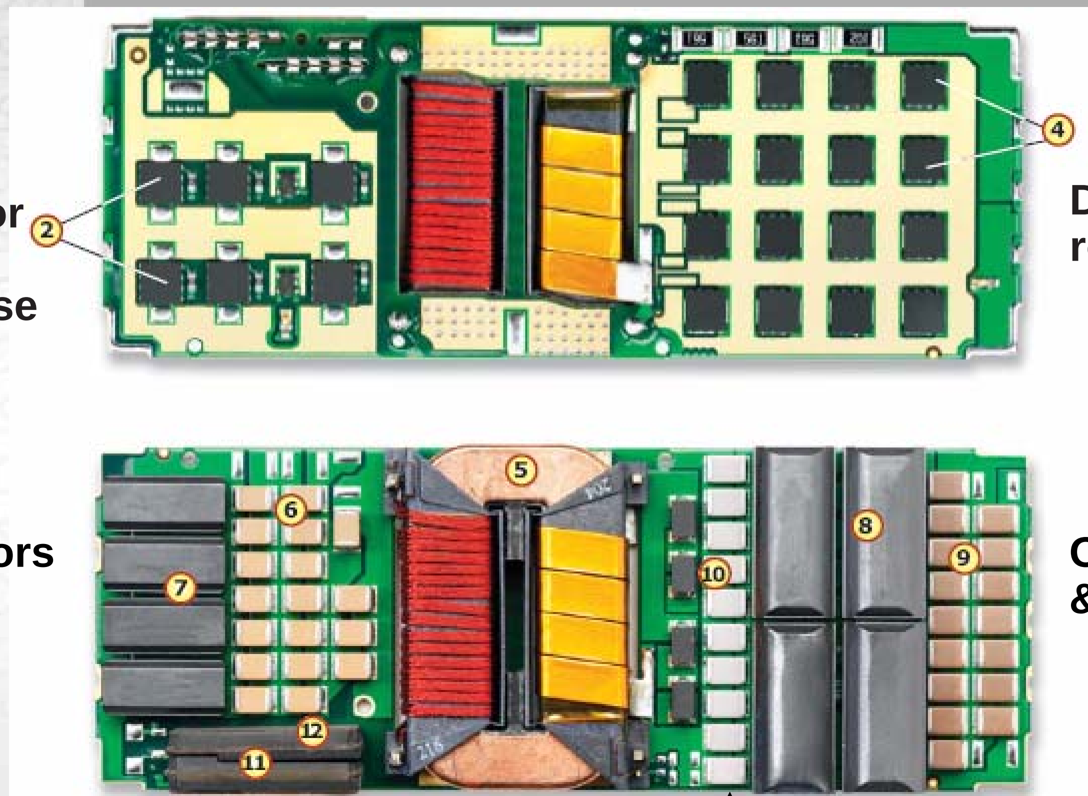
PP-2953D/U and PP-6224C/U combined power supply.

Fully interchangeable in form, fit, and function with the previously fielded power supplies.

DC-DC Module

MOSFETs.
Main switch and common drain for low conducted and radiated noise

Dual diode rectifier



Input capacitors & inductors

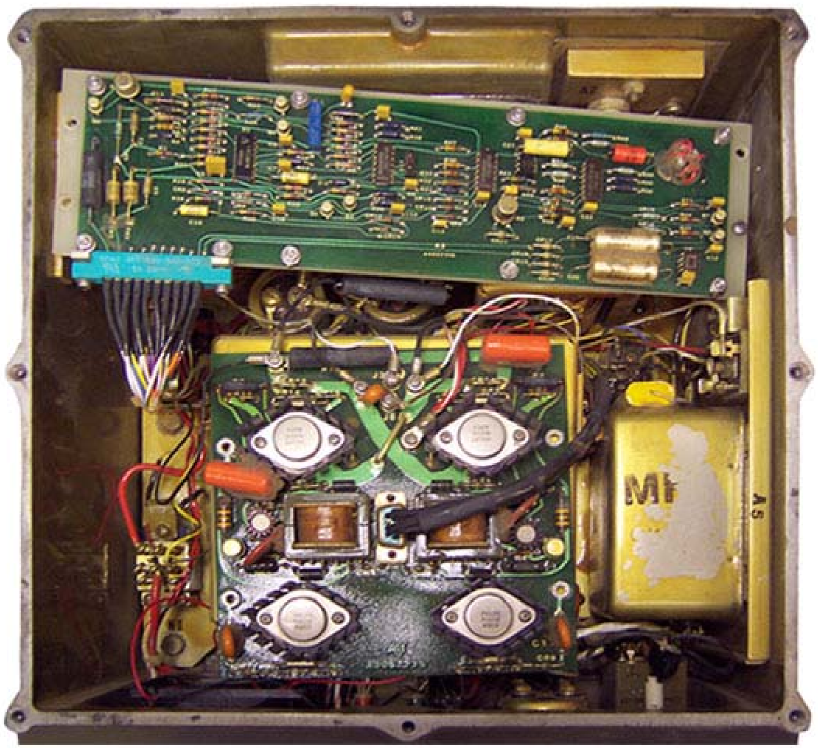
Output capacitors & Inductors

"Brains".
Primary and secondary control devices (ASIC)

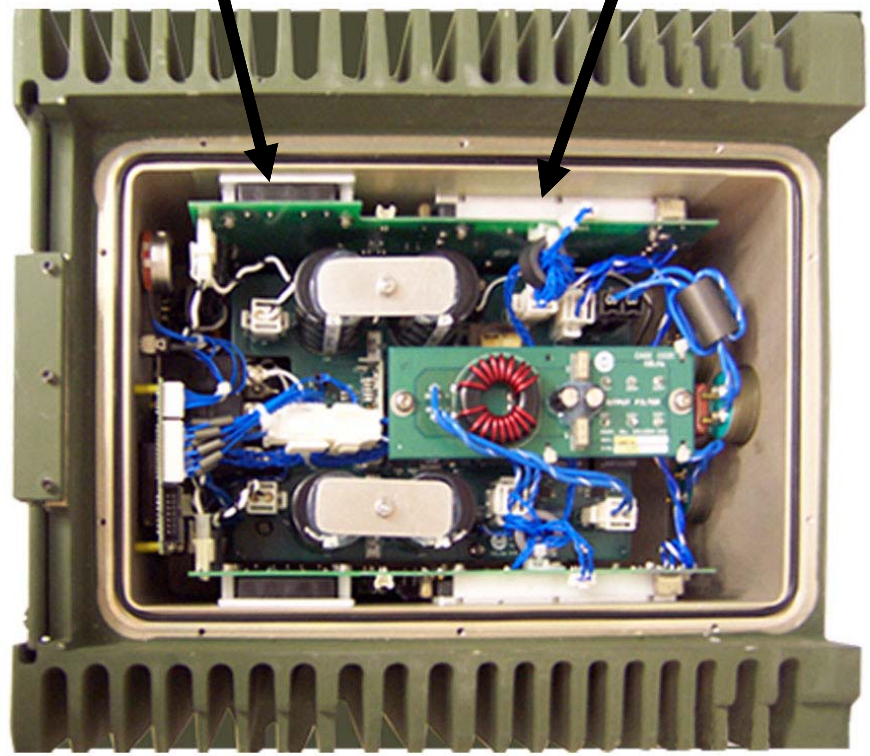
Main Transformer

Resonant capacitors.
Quasi-resonant tank for zero-current-switching converter

PFC DC-DC



Old



New

Added Features

- Improved cover design:
  - Longer hinge length.
  - Hinge “pin” part of one-part lid.
  - Lid protected from shear when fully open.
- Front panel recessed so items are protected from shear.
- Environmental improvements:
  - Sealed.
  - Old supply used a fan which was another low reliability point.

Note

- Spec did not call for design without a lid, just an "improved" lid. In fact, spec says:
  - "3.3.2.1 Cover. A cover shall be installed to protect the front panel."
- Front panel elements are mostly sealed:
  - Potentiometer chosen is not sealed due to cost but could have been.
  - LCD/LED cover is thin and sealed unless punctured.

Note

Recessed front panel
+ Totally sealed unit

No need for cover lid at all!

Note

- Lesson:
  - Step back.
  - Look at existing use, possible future use, and possible improvements.
  - Ask.

Added Features

- Auto voltage ranging:
  - 115 VAC +/- 10%
    or 230 VAC +/- 10%
  - Can really handle any voltage
    85 – 264 VAC, but by spec we had to put in an "undervoltage" changeover to battery bypass for 230 VAC nominal operation.
  - Old supply says: "Applying 230 VAC when switch is in 115 V position will damage Power Supply."
- Power factor correction
  - Old supply had no PFC.

Added Features

- Overcurrent:
  - ‘OC’ displayed.
  - Old supply had no indication.
- Battery wiring reversed:
  - ‘888’ displayed.
  - Use of battery is disabled until polarity fixed.
  - Old supply says: “Reverse polarity will cause equipment damage.”

Note

- Battery charging:
  - Old power supplies were used for battery charging (foldback current limit then constant voltage for final stage).
  - DC-DC converter technology chosen has current limiting, but does not have foldback current limit, so if the current is high, but not high enough to open the CB, our automatic current limiting circuitry turns off the output for a time and tries again a little later.

Added Features

- Improved efficiency:
  - reduction in the amount of waste heat dissipated per watt of output:
    - permits convection cooling.
- Mechanical design permits stacking 10 high.

Added Features

- Improved reliability:
  - No fan:
    - fan is high failure point.
    - reduces airborne contaminants such as dust and sand.
    - eliminates changing air filters.
  - >90% probability of 5,000 hours failure-free operation.
  - MTBF over 99,000 hours.

PP-2953D/U and PP-6224C/U

Contact Information

Custom Manufacturing & Engineering
2904 44th Ave. N.
St. Petersburg, FL 33714
(727) 547-9799
www.custom-mfg-eng.com

Rich Sidley
Rsidley@custom-mfg-eng.com

Moving Forward with Fuel Cells: Army CERDEC Development and Demonstration Progress

Elizabeth Bostic
US Army CERDEC Fuel Cell Team Leader

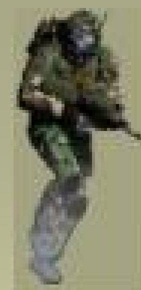
Agenda

- Current Program Paths
- Performance and Status Update
- Issues
- Future Program Paths and Demos

Mounted/Dismounted Soldier Power Army Technology Objective

FY05	FY06	FY07	FY08

FFW ATD — LW Blk III — PM-CSS STEP — PEO Soldier



TRL=6
Demo power mgnt at chip level
METRICS:
- soldier electronics at 50% savings over current power levels

TRL=5
250W Manportable field charger
METRICS:
- Liquid fuel
- <10kgs

TRL=5
20W Fuel Cell/rechargeable battery hybrid
METRICS:
- Methanol fuel
- 600whrs/kg @72 hrs
- 1.5 lbs "dry"

TRL=5
2kW quiet powe source
METRICS:
- <150 kgs, JP-8
- Noise 69 dBA

=5
V quiet power/cooling ystem
RICS:
- P-8; 50% fuel savings

TRL=6
Demo improved soldier suite processors
METRICS:
- soldier electronics at 75% savings over current power levels

TRL=6
20W fueled hybrid power source
METRICS:
- Packaged fuel
- 700whrs/kg @72 hrs
- 1.5 lbs "dry"

TRL=5
250W Manportable field charger
METRICS:
- JP-8
- <10kgs

Pacing Technologies:

Meso-components	Burner control/Heat-driven cooling	Power Management Power integration

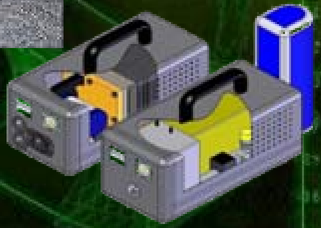
Fuel Cell Focus Areas

Soldier and Sensor Power (1-100W)	Battery Charging (100-500W)	Auxiliary Power Units (500W-10kW)

GOALS (FY08):
- 20 W, packaged fuel
- 700 Wh/kg (72-hr mission)
- 0.7 kg (dry)

Ultracell XX25 EVT
- 20W RMFC
- 1.1kg dry weight
- 23% system efficiency
- 360 W-hr/kg (72 -hr mission, 20W)

GOALS (FY08):
- 250 W
- < 10 kg (dry)
- JP-8



250W Battery Charger
- Methanol / water mix
- 15+kg system weight
- ~15% efficiency

GOALS (FY08):
- 2 kW, JP-8 fueled
- < 150 kg (dry)
- Noise < 69 dBA

GD / Aspen 5kW
- Logistics Fuel Reformer (CPOx)
- 799 ppm (wt) sulfur species in JP-8 tested successfully (no sulfur out)
- Reformate suitable for SOFC (<2.5% CO_2 + methane + acetylene, with balance 49%N_2, 24.5%H_2, and 24%CO)

Program Update: Current Status and Performance Metrics

Soldier Power Fuel Cell
ATO Efforts

Ultracell Corporation

- 20W Reformed Methanol Fuel Cell
- Developed as part of ATO Program

Dimensions: 9.1’’ X 6.1’’ X 1.9’’
Start-Up Time: ~26 min consuming 18 g of fuel
System Dry Weight: 1.1 kg
Fuel Cartridge Weight: .325-.350 kg

24 hr mission weight : 2.25 kg
72 hr mission weight : 4.35 kg

Efficiency: 23.8% @ 20 watts
Fuel Cartridge Duration: 9 hours

72 hr mission energy density: 360 W-hours/kg

Ultracell Testing

- Tests completed at CERDEC - Fort Belvoir, VA
  - Fuel Consumption
  - Electrical Characterization
  - Orientation
  - Environmental
  - Max Power
  - Lifetime (in progress)
  - Thermal signature

- The 12 units CERDEC has received have logged over 1500 hours total, the most run hours logged by one unit is 300 hours

- Areas of Improvement and Future work
  - Thermal Management
  - Pump Development
  - Compressor Development
  - Reformer Work
  - Cartridge Development

Night Vision Compatibility

Smart Fuel Cell -DACP

DACP Goal - Develop a fuel cell with a similar form factor to the Li-145 battery that reduces weight and increases energy density for Soldier missions

- Dimensions: 9.75” x 2.31” x 3.06”
- System Dry weight: 1.18 kg
- Fuel cartridge: 500 ml / 0.47 kg
- 24 hr mission weight: 1.6 kg
- 72 hr mission weight: 2.6 kg
- Efficiency: 22.4%
- Fuel Cartridge Duration: ~24 hours
- Fuel is 100% methanol at low temp; water/methanol mix at high temp >40ºC
- 72 hour mission energy density 554 W-hr/kg

SFC Roadmap 2003-Present

				Noise	Energy	Orientation
System	Year	Weight (kg)	Operating Temp	at 1 m dB(a)	Density (wh/kg)	Independent
A25	2003	7.8	15° C - 35° C	40	150	N
C25	2004	1.7	1° C - 30° C	40	219	N
C20-MP	2005	2.0	5° C - 30° C	45	373	N
C20-D	2005	2.0	5° C - 50° C	45	259	N
FCPS	2006	1.2	1° C - 35° C	42	553	N
Alpha I	2007	1.4	Not Enough Information			N

A25

C25

C20 – D / MP

FCPS

Alpha I

AMI - Collaboration Efforts

CERDEC leveraged DARPA and SOCOM work with AMI and plans on future collaboration efforts.

Power:	20 W
Start Up Time:	20 minutes
Dimensions:	11.6’’ X 3.7 ’’ X 5.11’’
System Weight:	1.55kg
Fuel Cartridge Weight:	0.406kg
24 hr mission weight:	1.95 kg @ 20 Watts
72 hr mission weight:	2.77 kg @ 20 Watts
Fuel Cartridge Duration:	25 hours @ 20 Watts
Energy Density:	520 W-hours/kg (72 hrs@ 20 watts)

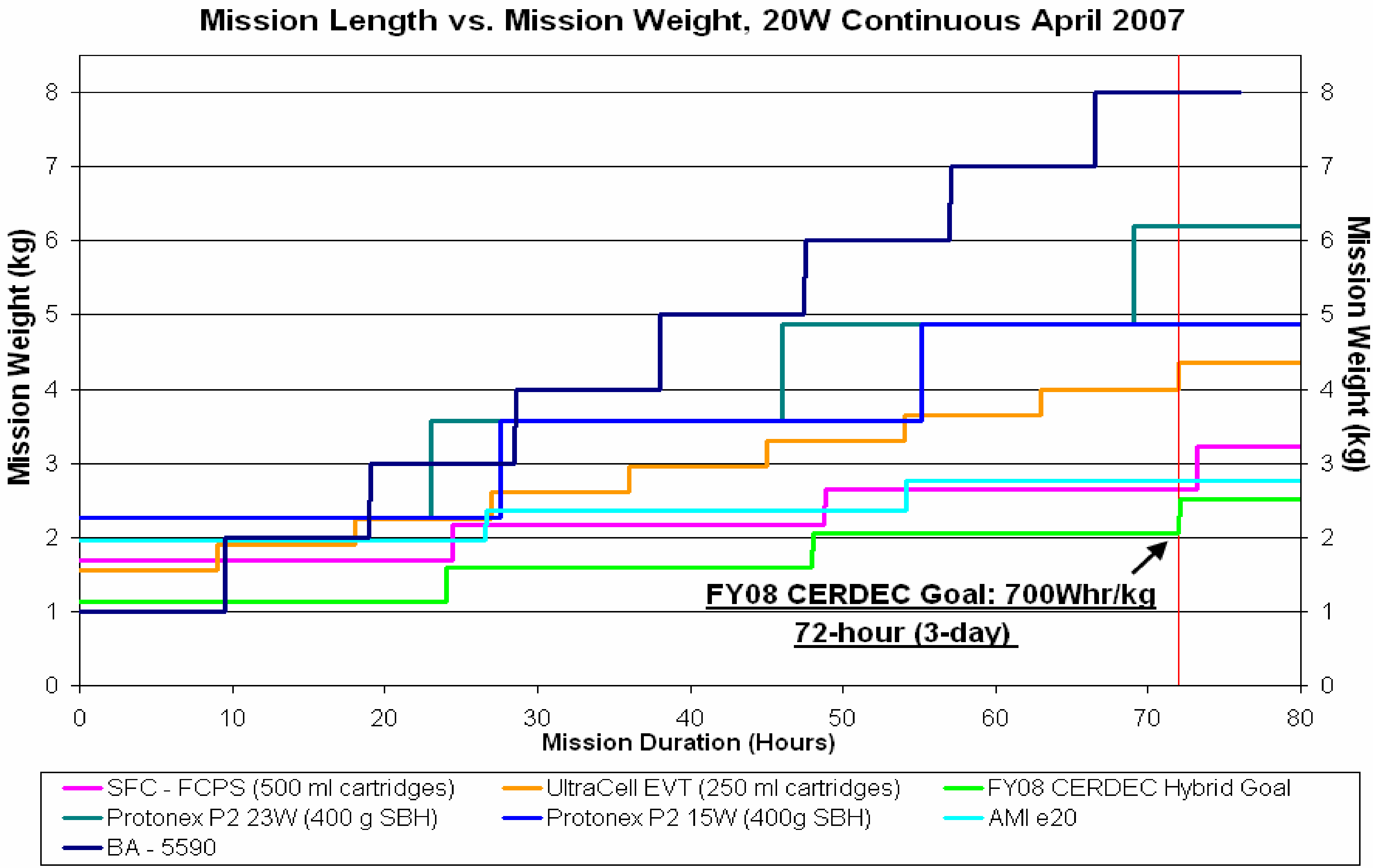
Protonex P2 ~ $NaBH_4$ PEMFC

In Testing with CERDEC
Rated 30W continuous
PEFC with Sodium Borohydride Fuel

Dimensions:	7.2’’ X 7.2’’ X 3.6’’
Start Up Time:	<1 min.
System Dry Weight:	0.96 kg
Fuel Cartridge Weight:	1.32 kg (hydrated)
24-hr Mission Weight :	3.60 kg
72-hr Mission Weight :	6.24 kg

24-hr, 30W Mission Energy Density:
200 W-hours/kg
72-hr, 30W Mission Energy Density:
350 W-hours/kg

Soldier Power Competition



Mid-Range Fuel Cell ATO Efforts

Idatech

- 250W Reformed Methanol Fuel Cell
- Developed as part of ATO Program
- Application is a forward field battery recharger and stand-alone 250W power source

Dimensions: 13.5 x 6.25 x 19.1 inches

Weight: ~15kg

Efficiency: 15.4% @ 200W

Fuel Consumption: 500ml/hr

Idatech Testing

- Tests completed at CERDEC - Fort Belvoir, VA
  - Fuel Consumption
  - Electrical Characterization
  - Orientation
  - Environmental
  - Max Power
  - Thermal Signature
  - Acoustic Signature

- Two units at CERDEC have logged 140 and 103 hours
- Life Testing at Idatech reports 1240 hours of operation
- Future Work will focus on
  - Increased system efficiency and reliability
  - System weight and volume reduction
  - Integrated starting capability
  - Study system weight and volume savings for single box configuration vs. modular

Congressional Programs

Giner Electrochemical Systems

- 250W Field Ruggedized Direct Methanol Fuel Cell
- Lightweight (<10 kg dry weight) and compact for easy portability
- 250W is a versatile power level for charging multiple batteries simultaneously and/or powering equipment

Idatech

- 3kW Tactical Fuel Cell Generator
- Design, fabricate, assemble and test a 3 kWe autothermal reforming PEM fuel cell power unit with regenerable desulfurizer and polishing bed.

General Atomics

- Solider Power Fuel Cell – Ammonia Borane Fuel Cell Development
- To develop a portable hydrogen generator which utilizes the pyrolysis of ammonia borane (AB) and integrate with a 20W PEM fuel cell to prove its performance in a laboratory demonstration.

Congressional Programs cont'd

Ensign Bickford Aerospace & Defense

- Ammonia Borane Fuel Cartridge **Development**
- Develop a high fidelity demonstration of a hydrogen fuel cartridge
  - 3% gravimetric hydrogen production
  - 4 hour continuous operation connected to a fuel cell

NanoDynamics

- JP-8 Solid Oxide Fuel Cell Development
- Development and testing of a full scale 250W portable technology demonstrator operating on JP-8.

Tennessee Technological University

- Advanced Portable Power Institute
- Includes 8 research projects from Tenn Tech, Vanderbilt University, University of Missouri – Columbia, & the International Technology Center.
- Projects focus on Li-Ion Batteries, Hybrid Power Sources, SOFC anodes, thermo-electrics, and other areas of power generation.

The Issues

Technical Challenges

Across the Board…

- Rugged System, durability in harsh environments
- Reduce System Size and Weight
- Reliability
  - Balance of Plant Components
  - Air side contamination
- Water Management
- Reduce Acoustic and Thermal Signatures
- Orientation independent operation
- Power Quality
- Unit Cost

Temperature Extremes

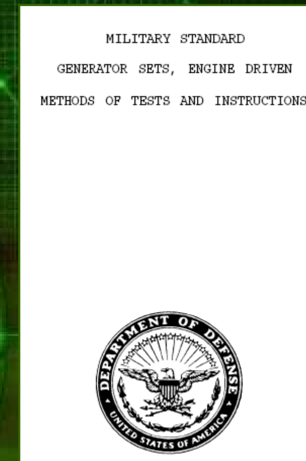
Baghdad 691734

Max Temp:	51 °C
R.H @ Max Temp:	6%
Lowest Recorded R.H:	5%
Average Temp. [Annual]:	24 °C
Average R.H. [Annual]	39%

Data Courtesy of:
Paul F. Krause, Ph.D.
U.S. Army Topographic Engineering Center

Testing Specifications

- Operating and storage temperatures (-30°C to 50°C)
- Shock and vibration, drop test
- Acoustic & Thermal Signatures → Non-Detectability
- Humidity (high and low); rain and moisture, altitude
- EMI
- Electrical characterization, including peak power durations
- Thermal Cycling
- Start and Stop scenarios and durations
- Air side contamination resistance
- Human factors → user friendly
- Reliability
- Maintainability


MILITARY STANDARD
GENERATOR SETS, ENGINE DRIVEN
METHODS OF TESTS AND INSTRUCTIONS
DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

Areas for Improvement

Development of commercial Market

- Reliability
- Performance metrics
- Efficiency

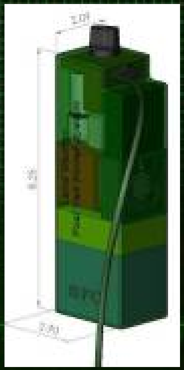
Plans for this Year

Activities

- PM C4ISR OTM Demo – Ft. Dix, NJ
  - Sensor Applications - Textron
  - Robotics Applications - iRobot
  - Future Force Warrior
- Safety Assessment Reports
  - Currently Ultracell and SFC have limited safety approval for field testing
- Field Demos and Testing
  - Currently initiated mostly by Industry

Fort Dix Demonstration 2006

Soldier System Hybrid Power Concept



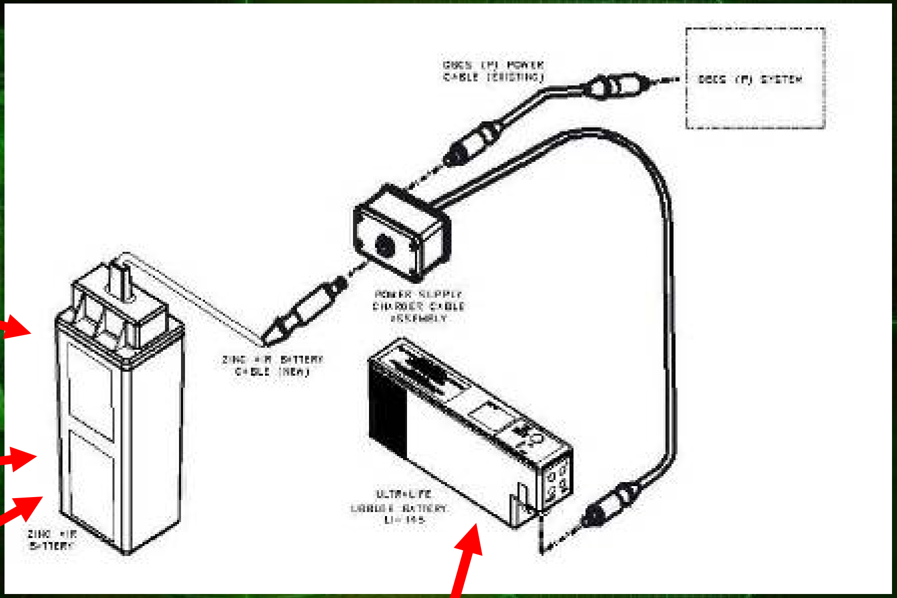
DuPont/SFC M-25

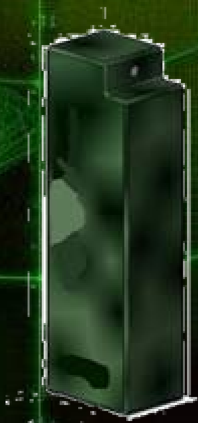
OR

UltraCell-XX25™

OR

Electric Fuel BA-8150
Zinc-Air Battery





Ultralife
LI-145 Battery

Programmatic Plans

- DARPA Robust Portable Power Sources Program
- Working on development of **FY09** ATO
  - Potentially looking at smaller power (sensors)
  - Fuel cells in 50W and 75W range
  - Fuel Cell for Robotics power
  - Targeting specific applications, not just areas

Conclusion

- The Army is looking for **total system solutions & appropriate applications.**
- Smaller systems are closer than larger systems to be transition ready.
- Maximize functionality and run-time of military power sources.
- Past year has show rapid development and significant improvement towards meeting the Soldiers need.
- CERDEC Testing shows major areas of development:
  - Reliability
  - Ruggedization
  - Efficiency
  - Light weight & compact
  - Energy Density

Questions?

Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications

Joint Services Expo, San Diego, CA
Apr 24-26, 2007

Shailesh A. Shah
Marketing Director, Military

Millennium Cell Inc.
One Industrial Way West
Eatontown, NJ 07724
shah@*millenniumcell.com*
732-542-4000

Who is Millennium Cell?

- The Hydrogen Battery Technology Company
  - Formed in 1998 and went public in 2000
  - Ticker symbol “MCEL”, NASDAQ market
- Hydrogen storage and passive PEM systems
  - **Chemical hydride expertise**
  - **Recently acquired Gecko Energy Technologies, a passive PEM fuel cell company**
  - Over 30 patents granted and 74 pending
- Focused on portable applications under 500 watts

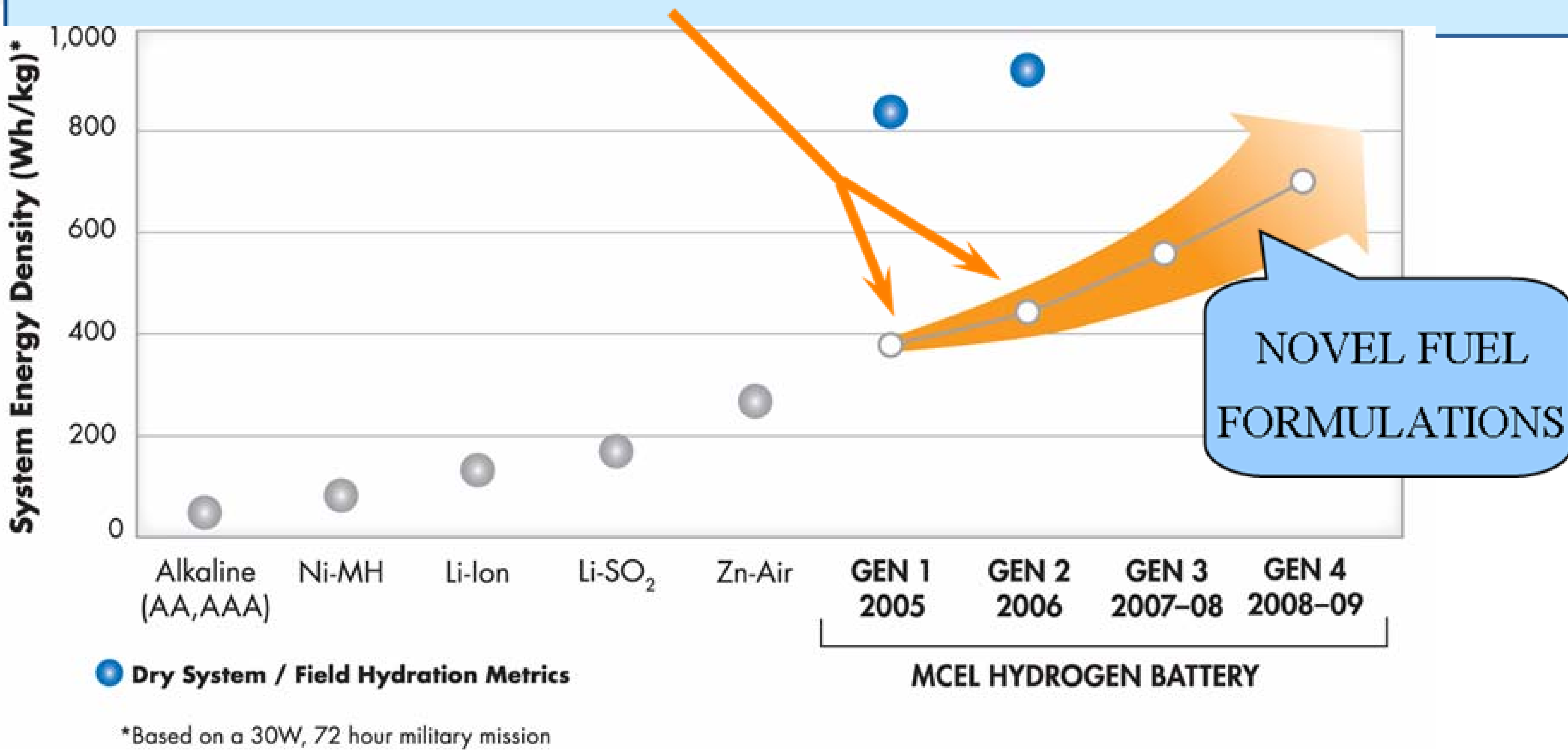
Strategic Relationships

- Collaboration to accelerate the commercialization of portable fuel cells
- Portable System Development
  - PEM fuel cell developers and licensees
  - Military development programs
  - Working with non-profit groups

Hydrogen Battery Technology
Hydrogen on Demand® Reaction

Millennium Cell
The Hydrogen Battery

$$\underbrace{NaBH_4\ (aq) + 4\ H_2O}_{\text{An energy-dense chemical hydride fuel}} \underbrace{\xrightarrow{cat}}_{\text{Rapid } H_2 \text{ production}} \underbrace{4\ H_2}_{\text{High purity hydrogen}} + \underbrace{NaB(OH)_4\ (aq)}_{\text{Borate can be recycled or disposed}} + \underbrace{heat}_{\text{No heat input}}$$



shah@ millenniumcell.com, (732)-544-5739, www.millenniumcell.com

Multiple Platforms for Military Applications

Millennium Cell
The Hydrogen Battery Technology Company

- **Sub 20 Watt Passive Platform**
  - Long run time wireless sensors
  - Rugged IT
- **20 – 100 Watt Platform**
  - Soldier Power
  - Military Radios
- **100 – 300 Watt Platform**
  - UAV, UGV
  - Battery Charging
  - Medical Evacuation
- **500 Watt Platform**
  - Critical Emergency Power
  - Remote Power

- **High Energy Density Fuel**
  - Less Weight
  - Less Volume
- **Safe**
- **Indefinite Shelf Life**
- **Fuel Gauge**
- **Hot Swappable Cartridge**
- **Silent Power**
- **Low Thermal Signature**

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Product Development

Passive platform for < 20 W applications

Millennium Cell
The Hydrogen Battery Technology Company

- Initial demonstration system
- Uses Gecko passive PEM fuel cell
  - High power density → fits in device
  - High efficiency → lower waste heat
  - Simple architecture with minimal BOP
  - Low cost → < $5 per watt
  - Thin, flat form factor → no extra volume
- Passive HOD™ system
- Target Applications:
  - wireless sensors,
  - handset chargers,
  - wearable power,
  - perimeter security

Night Vision Camera

First demonstrated in Sep 2006

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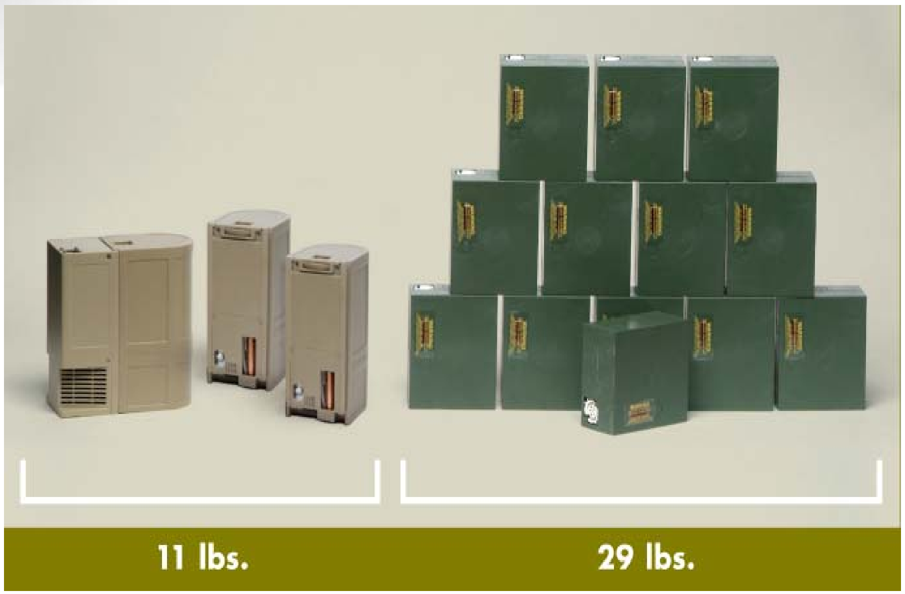
Product Development

Protonex + Millennium Cell

Millennium Cell
The Hydrogen Battery Technology Company

30W Soldier Power System



- 30 W x 72 hour mission
- 66 % Lighter than BA 5590
- 20 % Cheaper

150W UAV Power System

- Enables 4X – 6X Flight times

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Product Development
Jadoo + Millennium Cell

Millennium Cell
The Hydrogen Battery Technology Company

SOCOM PSC-5D Radio

- 55 W nominal power
- Fits in 2 x BA 5590 battery box

N-StorNB

e<u>X</u>tended <u>R</u>un <u>T</u>ime

- 100 W Auxiliary Power
- 2200 Wh Energy
- 110 V, 12 V interface

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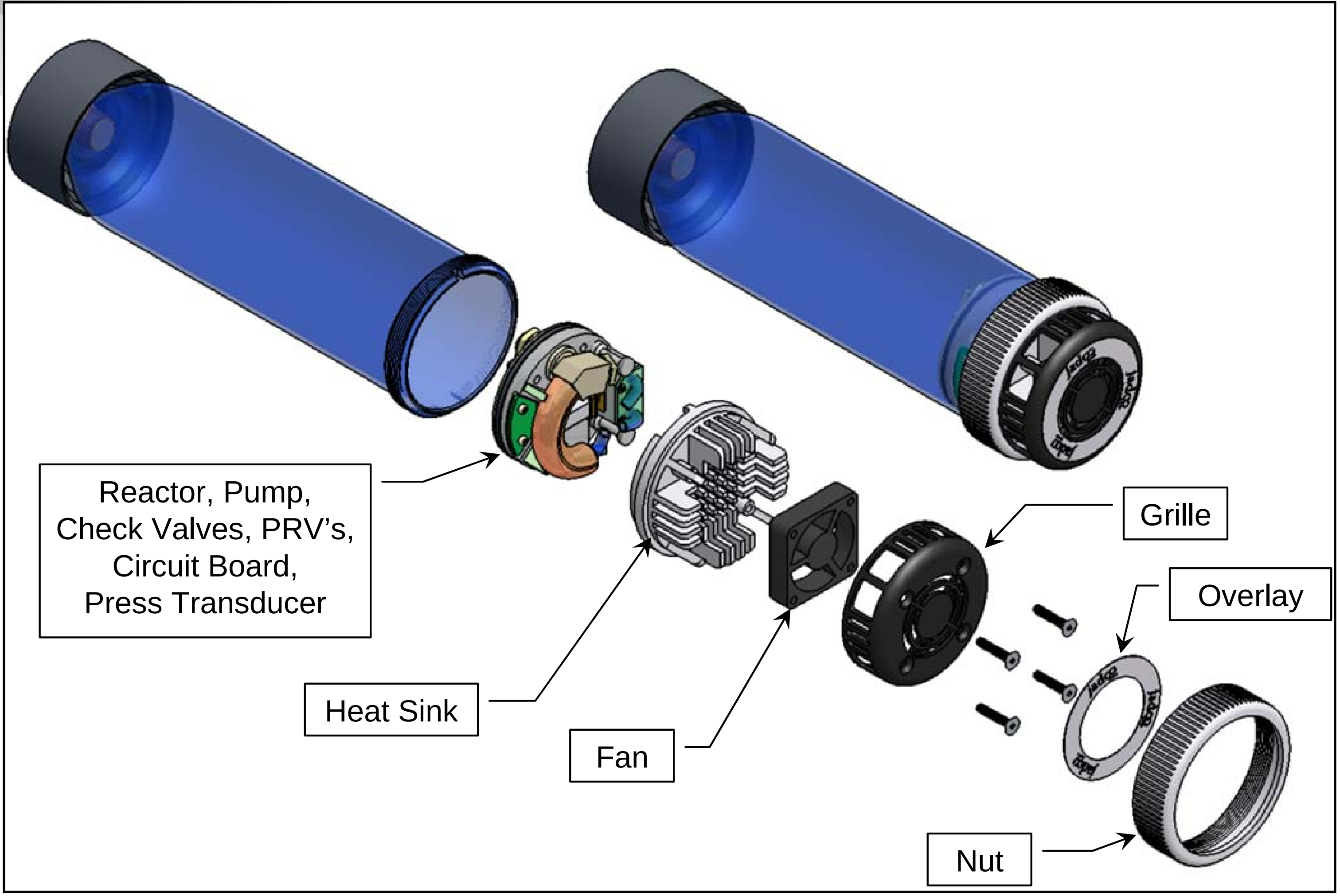
Cartridge Detail View
N-StorNB (NB: Sodium Borohydride)

Millennium Cell
The Hydrogen Battery Technology Company



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Value Proposition

Special Operations Radio

Millennium Cell

The Hydrogen Battery Technology Company

Based on 11 day mission	Jadoo & MCEL Fuel Cell System	BA-5590 Battery
Configuration for mission	1 Fuel Cell 7 x 500 W-hr Fuel Cartridges	35 Battery Packs
Weight of System	11 kg (24 lbs)	36 kg (79 lbs)

Status: First prototype demonstrated Sept. 2006
Delivery to SOCOM in Q2-07

Competitive: Advantage
Field hydration, non-flammable fuel
66% lighter than BA5590

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Product Development

Cartridge manufacturing

Millennium Cell

The Hydrogen Battery Technology Company

- Development programs to establish manufacturing technologies for cartridge components
  - Catalyst material / reactors
  - Fuel / byproduct assemblies
  - Cartridge shell
  - BOP components (e.g., pumps, valves)

- Materials and processes scaleable to higher volume production
- Recently established in-house manufacturing capacity to support initial cartridge sampling
  - ~250 cartridges for evaluation in South Carolina in 2007-8

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Summary

- Significant Sodium borohydride ($NaBH_4$) expertise
- Novel Fuel Formulations offer higher energy density
- Portable systems being evaluated by military partners → Field Trials this year
- Technology development → product development / manufacturing
- Developing 3 – 5 Watt passive fuel cell systems

Thank you!

shah@ millenniumcell.com, (732)-544-5739, www.millenniumcell.com

Protonex

Portable, JP-8 fueled battery charger for remote operation and portable solid oxide fuel cell systems

2007 Joint Service Power Expo
April 26, 2007

Protonex

Outline

- Introduction
- Why portable SOFCs?
- SOFCs at Protonex
- Technical approach
- 250 W battery charger
- 75 W battery charger
- Summary

Mesoscopic Devices

POWERED BY Protonex

Mesoscopic Devices, LLC
merged with Protonex in April 2007

Protonex

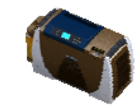
PROTONEX OVERVIEW

- Leading provider of 10 - 1000 watt PEM and SOFC power solutions
  - Portable, remote and mobile power
  - Targeting applications underserved by batteries and small generators
  - World class developer of pumps, blowers and meso-scale reformers
- Developing products for military and commercial applications
  - High performance and low cost
- Facilities in Southborough, MA and Broomfield, CO

Protonex

PROTONEX PRODUCTS

- Fully integrated power systems – fuel in, power out
- Supporting multiple fuel types
  - Hydrogen, Chemical Hydrides, Methanol, Propane, JP-8
- Hydrogen PEM fuel cell technology
- SOFC technology



Valta™ 250 Multi-Purpose APU

150W & 500W Power Generators

75W SOFC Power System

ProPack™ C50 Man-Portable Power

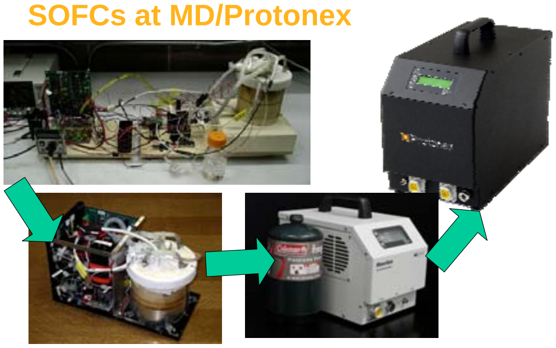
Protonex

Why portable SOFC generators?

- Relative to other power sources, SOFCs are:
  - Quieter than IC-engine generators
  - Lighter than batteries
  - More efficient than IC-engines
  - Longer maintenance interval than IC-engines
- Relative to other fuel cells, SOFCs offer:
  - High energy density (hydrocarbon fuels)
  - Widely available fuels
  - Simple fuel reforming
  - Wide environmental tolerance range

Protonex

SOFCs at MD/Protonex



Protonex

SOFC development approach

- 250 W battery charger
  - ONR program
  - JP-8 (desulfurized)
- 75 W battery charger
  - Commercial system
  - Propane
- Build family of generators

Protonex

SOFC technical approach

- Tubular solid oxide fuel cells
- Catalytic Partial Oxidation reforming (CPOX)
  - No water required
  - JP-8, propane
- Battery hybridization
  - Start-up, peaking power
- Optimized components

Protonex

Emphasis: integration, commonality

- Tightly integrated hot zone
- Stacks designed for integration
  - Mechanical
  - Fluid flow
  - Thermal
- Subassemblies in cold zone
  - Fuel delivery
  - Air delivery
  - Controls, sensing, power management

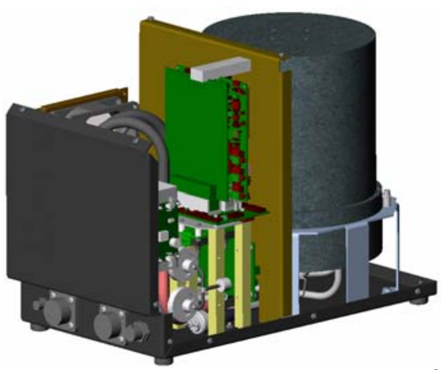
Protonex

250 W Battery Charger (ONR)

- Squad-level field battery charging
- Single button operation
- 7.1 x 9.6 x 13.1 in (180 x 245 x 332 mm)
- 13.7 lb (6.2 kg) dry
- Desulfurized JP-8 fuel
  - <0.8 gal/day (2.7 L/day) (prediction for current generation)

Protonex

Protonex



Protonex

Liquid fuel, stand alone desulfurizer

- Sulfur removal from liquid fuel
- Reduces sulfur from >3000 ppm to <10 ppm S
- Single sorbent bed, with automatic regeneration
  - <6 hours to clean fuel for a 24 hour test
  - <24 hours cycle (including regeneration)
- Multiple sorbent beds
  - Continuous regeneration
  - Highly compact
  - 5 kW model under development for TACOM

Protonex

SOFC generator status (ONR program)

- 2nd generation system in assembly
- Testing to begin May 1
- Additional test articles to be built through Aug. 07
- By September 2007
  - Bench testing at Protonex
  - Demo power generation and battery charging
  - Stand-alone operation
  - Unit to Navy for bench testing with desulfurizer to support testing

Protonex

MesoGen™ portable generator

- Propane fired
- Target: 75W nominal, 150W peak
- 12/24 VDC
- 8.5 lb (3.85 kg)
- 10.1 x 6.6 x 7.3 in 257x167x185 mm
- Advanced LSGM cells

Protonex

Complete system demonstration

- Cold start on propane
- Multiple start/stop cycles
- Long-term tests of key BOP components (up to 2000 hours)
  - Fuel reformer, blowers, fuel feed system
- Recent cell tests:
  - 1000 start/stop cycles—no tube failures
  - 3% degradation at 500 hours
- 58 W gross power in initial tests

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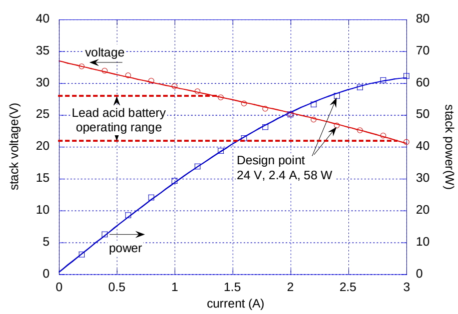
Protonex



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Summary

- Portable SOFCs offer significant advantages for military applications:
  - High energy density in fuel (>3000 Wh/kg)
  - Ability to use fuels already in theater (propane, JP-8 with processing)
  - Field or on-board desulfurization of JP-8 is practical
  - Protonex is moving aggressively to demonstrate SOFC generators for military applications

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Protonex

Acknowledgements

- U.S. Navy Contract N00014-05-C-0051

Protonex

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DURABILITY AND PERFORMANCE ISSUES OF PEM FUEL CELL SYSTEMS FOR PORTABLE APPLICATIONS

Presented By

Amir H. Chegini (Ph. D)

Associate Professor

Department of Chemical Engineering
Hampton University
Hampton, Virginia

Objectives:
Quantify and Improve PEM Fuel Cell Durability

- **This presentation will discuss key challenges facing PEM fuel cells for portable applications, the underlining reasons, and efforts toward overcoming these challenges.**
- **In addition, several specific methodologies that have been proven to be effective in enhancing fuel cell performance and durability will be illustrated.**

DURABILITY AND PERFORMANCE ISSUES OF PEM FUEL CELL SYSTEMS FOR PORTABLE APPLICATIONS

For PEM fuel cells technology to be successful in the market place as portable source of energy replacing batteries, it must be competitive in several key matrices, including:

- **Performance**
- **Durability**
- **Cost**
- **Weight & Volume**

Technical Challenges

- **Fundamental issues of PEM fuel cell durability and performance are usually due to either the membrane breach or due to the catalyst activity loss.**
- **Environmental factors strongly affect the performance, power density, life cycle cost and overall efficiency of fuel cell integrated power systems.**
- **Cost, Weight and dimension are other factors**

Quantify and Improve PEM Fuel Cell

2010 Technical Target: Durability with cycling 5000 hours

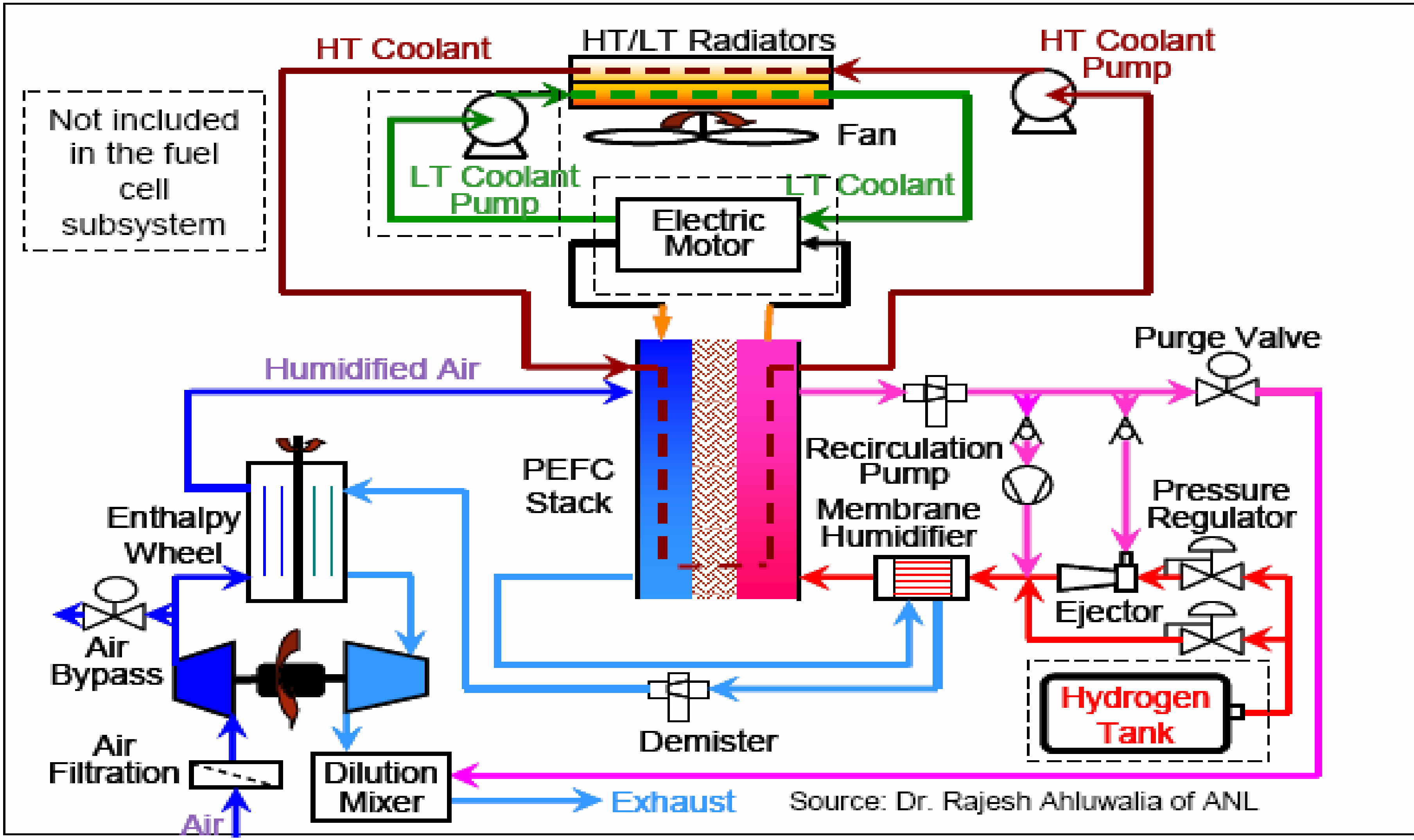
- **Design materials with improved durability**
- **Define degradation mechanisms**
- **Identify and quantify factors that limit PEMFC Durability**
- **Measure property changes in fuel cell components during life testing**
- **Life testing of materials**
- **Examine testing conditions, esp. drive cycle**
- **Membrane-electrode durability**

Quantify and Improve PEM Fuel Cell

2010 Technical Target: Durability with cycling 5000 hours (CONTINUED)

- **Electro-catalyst activity and stability**
- **Electro-catalyst and GDL carbon corrosion**
- **Gas diffusion media hydrophobicity**
- **Bipolar plate materials and corrosion products**
- **Develop/apply methods for accelerated and off-line testing**
- **Improve overall durability (mechanical,**

Overall System Configuration With Major Components



DURABILITY

Durability is one of the most critical remaining issues impeding successful commercialization of broad PEM fuel cell stationary and transportation for energy applications.

Approach to improved PEM fuel cell durability

Durability of fuel cell stack components remains in most cases:

- **Insufficiently understood**
- **Lack of understanding of most degradation mechanisms**
- **Lengthy testing times**
- **difficulty of performing *in-situ*, non-destructive structural evaluation of key components**

Proton Exchange Membrane (PEM) durability

Our approach to improved PEM fuel cell durability is to define the degradation mechanisms and to understand these mechanisms to allow design of improved fuel cell materials and components. We have shown that the loss of electro-active platinum surface area shown during operation is primarily due to growth in platinum particle size. Cathode particle size growth is dependent on temperature, time, relative humidity, and potential. Accelerated durability measurements showed particle size growth was accelerated at high potentials and temperature, but was decreased with lower operating relative humidity

Membrane durability

- **Proper water management and performance degradation, or durability, must be addressed before PEM fuel cells can be used to routinely power automobiles and homes.**

Water Management

A natural byproduct of using hydrogen and oxygen to produce electricity in a PEM fuel cell is water with waste heat being the other.

One challenge is maintaining the proper amount of water in a PEM fuel cell. Sufficient water in the membrane is needed to maintain its conductivity, whereas too much liquid water can result in flooding the cathode gas diffusion layer, which prevents reactant oxygen from reaching catalytic sites and causes performance deterioration.

Membrane Electrode Assembly (MEA) durability

- The fuel cell membrane-electrode-assembly (MEA) durability plays a vital role in the overall lifetime achieved by a stack in field applications.
- Within the MEA's electro-catalyst layers are three critical interfaces that must remain properly intermingled for optimum MEA performance:

  1- Platinum/carbon interface (for electron transport and catalyst support)

  2- Platinum/Nafion interface (for proton transport); and Nafion/carbon

  3- Interface (for high-activity catalyst dispersion and structural integrity)
- The MEA performance shows degradation over operating time, which is dependent upon materials, fabrication and operating conditions. Transient automotive operating conditions exacerbate degradation of fuel cell MEA durability and reliability. Specifically, power (or voltage) cycling simulating vehicle drive cycles increases the rate of electro-catalyst surface area loss1-2. Start-up/shut-down of the fuel cell can also lead to membrane

Present Research

This work is leading to better understandings in couple of important areas, including:

- **How liquid water is produced, transported, and removed efficiently in PEM fuel cells**
- **How PEM fuel cell performance degrades.**

Such understandings are key in finding ways to maintain the cells' long-term performance during normal and harsh (e.g. freezing) conditions and improving their durability.

Approach in combining computational Modeling with experiments

- To build a computational tool that can be used in designing fuel cells, eliminating the need to do experiments on every single part of them.

- We have been using ANSYS multi-physics finite-element computer code as the basic platform to develop 2-D performance models for PEM fuel cells. Understanding the key phenomena using experimental means will be incorporated into the computational models, both simplified and multi-dimensional.

Approach (Continued)

- **For the past year focus has been mainly on liquid water transport, developing a PEM fuel cell model that can be employed to simulate a fuel cell's performance diagnostic tests on fuel cells for phenomena discovery and model validation.**
- **Next tackle would be on the key technical issues of performance degradation or durability, including performance degradation under normal operating conditions and under freezing operating conditions.**

Durability and Reliability

- **The durability of fuel cell systems has not been established. For transportation applications, fuel cell power systems will be required to achieve the same level of durability and reliability of current automotive engines, i.e., 5,000 hour lifespan (150,000 miles equivalent), and the ability to function over the full range of vehicle operating conditions (40°C to 80°C). For stationary applications, more than 40,000 hours of reliable operation in a temperature at -35°C to 40°C will be required for market acceptance.**

Air, Thermal, and Water Management

- **Air management for fuel cell systems is a challenge since today's compressor technologies are not suitable for automotive fuel cell applications.**

- **In addition, thermal and water management for fuel cells are issues because small differences between the operating and ambient temperatures necessitates large heat exchangers.**

Improved Heat Recovery Systems

- The low operating temperature of PEM fuel cells limits the amount of heat that can be effectively utilized in combined heat and power (CHP) applications.
- Technologies need to be developed that will allow higher operating temperatures and/or more effective heat recovery systems and improved system designs that will enable CHP efficiencies exceeding 80%.
- Technologies that allow cooling to be provided from the low heat rejected from stationary fuel cell systems (such as through regenerating desiccants in a desiccant cooling cycle) also need to be

SYSTEM SIZE

- **The size and weight of current fuel cell systems must be further reduced to meet the packaging requirements for automobiles.**

- **This applies not only to the fuel cell stack, but also to the ancillary components and major subsystems (e.g., fuel processor, compressor/expander, and sensors) making up the balance of power system.**

COST Analysis

- The cost of fuel cell power systems must be reduced before they can be competitive with conventional technologies. Currently the costs for automotive internal combustion engine power plants are about \$25-\$35/kW; for transportation applications, a fuel cell system needs to cost \$30/kW for the technology to be competitive.
- For stationary systems, the acceptable price point is considerably higher (\$400-\$750/kW for widespread commercialization and as much as \$1000/kW for initial applications).

Concluding Remarks
Technical Challenges:

- Cost and durability are the major challenges to fuel cell commercialization.
- Size and weight are approaching targets but further reductions are needed to meet packaging requirements for commercial systems.
- Tolerance to air, fuel and system derived impurities (including the storage system) needs to be established.
- Operation at low relative humidity (Ph = 20 and <10% relative humidity at 80°C) and start-up from sub-freezing temperatures has not been established.
- The tolerance of fuel cell stacks to impurities not established.

Concluding Remarks (continued)

- **Cost, efficiency and packaging of fuel cell balance-of-plant components are also barriers to the commercialization of fuel cells.**
- **For transportation applications, fuel cell technologies face more stringent cost and durability requirements.**
- **In stationary power applications, raising the operating temperature of PEMs to increase fuel cell performance will also improve heat and power cogeneration and overall system efficiency.**
- **Fuel cell systems for consumer electronics need to have improved energy density to compete with batteries**

2007 Joint Service Power Expo

Military 3 kW Jet-Fueled Tactical Fuel Cell Generator

April 25, 2007

San Diego, CA

Terry Dubois – U.S. Army CERDEC
John Lewis, Eric Simpkins, Jim Stephens
IdaTech, LLC
Mark Fokema, Aspen Products Inc.

ASPEN PRODUCTS GROUP, INC.

Appreciation to Joint Service Power Expo organizers for the opportunity to present today!

This presentation is a cooperative between:

- U.S. Army RDECOM Communication-Electronic Research Development and Engineering Center (Ft. Belvoir, VA)
- IdaTech, LLC, Bend, OR
- Aspen Products Group, Marlborough, MA

Army Fuel Cell Structure

Soldier & Sensor Power

Portable Power Generation

Stationary Power

Focus on System Development, Test, Demonstration, and Transition

Communications-Electronics, Research Development and Engineering Center

(CERDEC)

Tank & Automotive Research Development and Engineering Center

(TARDEC)

Army Corps of Engineers Construction Engineering Research Laboratory

(CERL)

Focus on Basic Materials R&D, Components, and Testing

Army Research Laboratory (ARL)

Army Research Office (ARO)

Army CERDEC Fuel Cell Focus Areas

Soldier and Sensor Power (1-100W)

GOALS (FY08):
- 20 W, packaged fuel
- 700 Wh/kg (72-hr mission)
- 0.7 kg (dry)

Ultracell XX25 EVT
- 20W RMFC
- 1.15 kg dry weight
- 23.16% system efficiency
- 340 W-hr/kg (72 -hr mission, 20W)

Battery Charging (100-500W)

GOALS (FY08):
- 250 W
- < 10 kg (dry)
- JP-8

IdaTech 250W Battery Charger
- Methanol / water mix
- ~15 kg dry weight (w/o battery)
- ~15% system efficiency

Auxiliary Power Units (500W-10kW)

GOALS (FY08):
- 2 kW, JP-8 fueled
- < 150 kg (dry)
- Noise < 69 dBA

GD / Aspen 5kW
- Logistics Fuel Reformer (CPOx)
- 799 ppm (wt) sulfur species in JP-8 tested successfully (no sulfur out)
- Reformate suitable for SOFC

Corporate Overview

IdaTech is a leader in the development of fuel processors and integrated fuel cell systems for portable power, critical backup power and remote power applications world-wide.

- Founded in 1996, in Bend, Oregon, USA
- World class energy technology company focused on the commercial deployment of PEM fuel cell products
- Wide range of fuel processing capabilities to produce high purity hydrogen from a variety of fuels
- Market- and application-driven fuel cell solutions for backup, industrial remote and portable power applications
- Deploying systems worldwide with partners in North America, South America, Europe and Asia

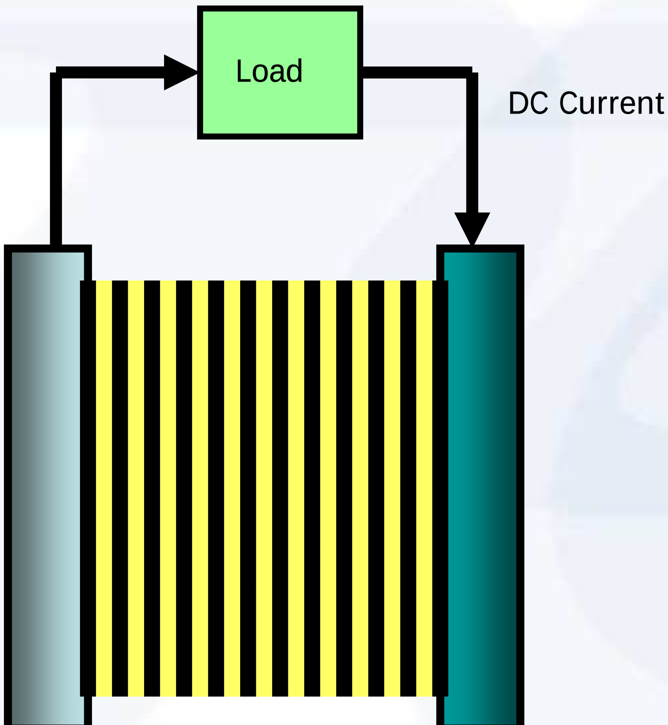
IdaTech

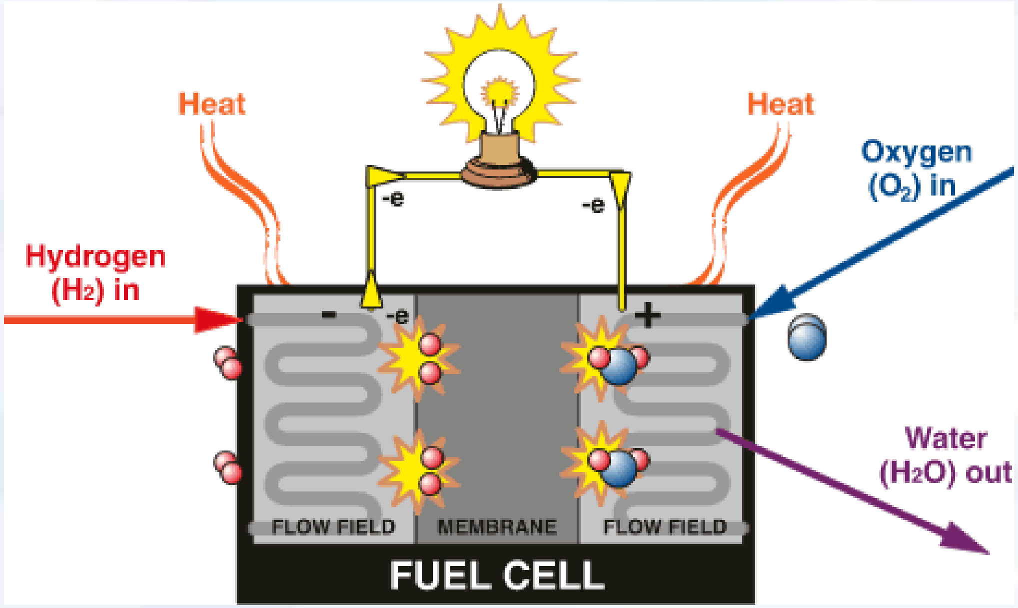
ISO 9000:2001 Certified

PEM Fuel Cell Stack

Two families of fuel cells – high & low temperature

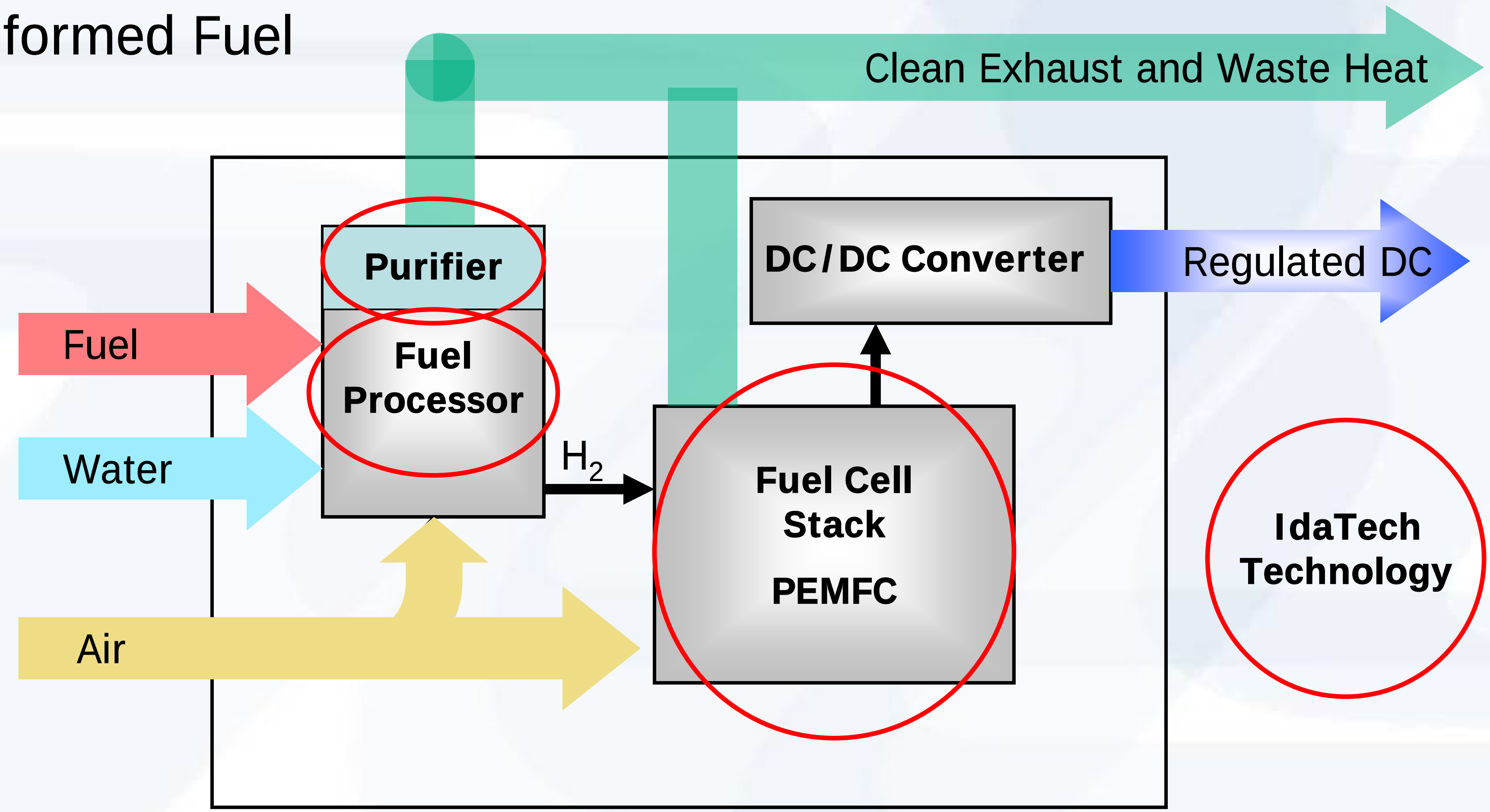
Primary low temperature types: AFC (alkaline); PEMFC (proton-exchange membrane); DMFC (direct methanol)



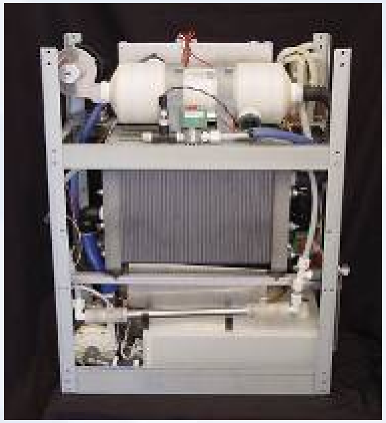


Proton Exchange Membrane Integrated Fuel Cell Power Systems

Reformed Fuel



IdaTech Patented Technologies

Fuel reforming	HyPurium™ membrane module	FC stack / power module
		
• High efficiency • Compact • Load following • Approaching 210,000 hours combined experience	• Up to 50% reduction in size & complexity • "Universal" fuel purification • >85,000 hours of testing / operation • Sulfur tolerant	• Efficient • >8000 hours life • Modular technology

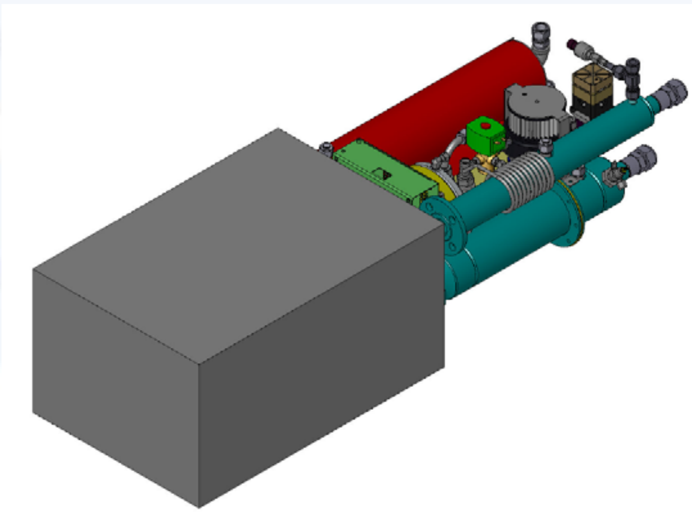
Fuel Cell Systems for Defense Applications

- *3 kW_e Tactical Fuel Cell Generator*

- **250 watt Fuel Cell Battery Charger (and small Tactical Generator)**

Relevant to 2 of 5 Soldier Modes of Maneuver: dismounted & air assault

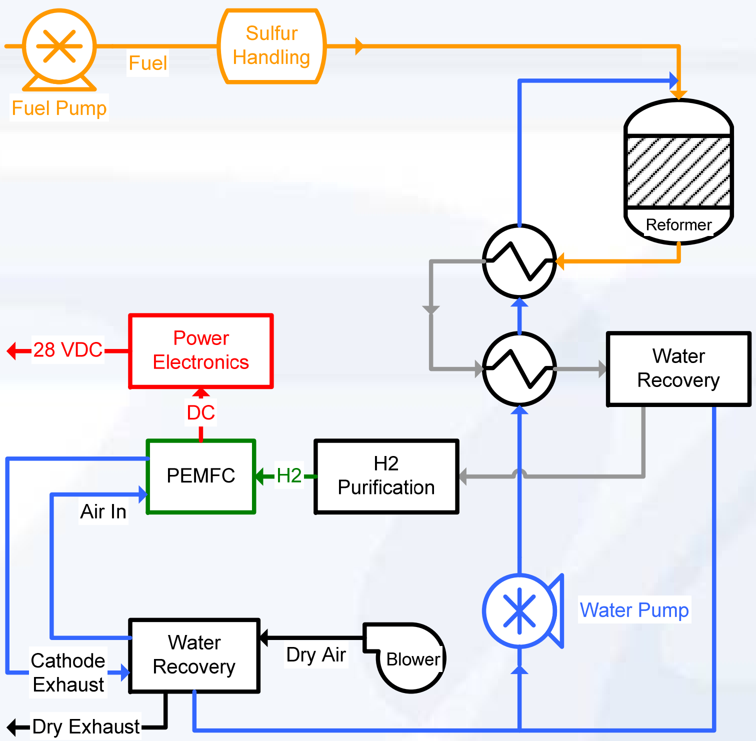
3 kW$_e$ Tactical Fuel Cell Generator



Need – small, soldier-portable military generator, fueled with military logistic fuels, with low signatures, efficient operation and minimal logistic tail

Operational Gap – Current TQGs require significant maintenance, are fuel inefficient, and are not quiet. The TFCG will significantly reduce maintenance, fuel consumption and have minimal signatures

Tactical Fuel Cell Generator



Conceptual Process Diagram

- Program initiated in August, 2006
- Army CERDEC is PM
- Well-funded through FY 2008
- Industry Team:
  - IdaTech (PM; PI - fuel processing, fuel cell; system integration)
  - Aspen (APG) – desulfurization
  - Military packaging company
  - Army Corps of Engineers's Fuel Cell Test & Evaluation Ctr.

Tactical Fuel Cell Generator

Technical Targets

- 3 kW_e (net) power @ 24 – 28 VDC / 120 VAC
- 100 liter volume (at 5 kW_e)
- DF2 and JP-8 compatible up to 3,000 ppm sulfur
- 1,000 hour maintenance interval
- Water neutral or nearly so
- MIL-STD-810F compatible similar to TQGs, e.g. temperature -40 to 50˚C (cold temp. kit may be required)

Technology Development Milestones to Date

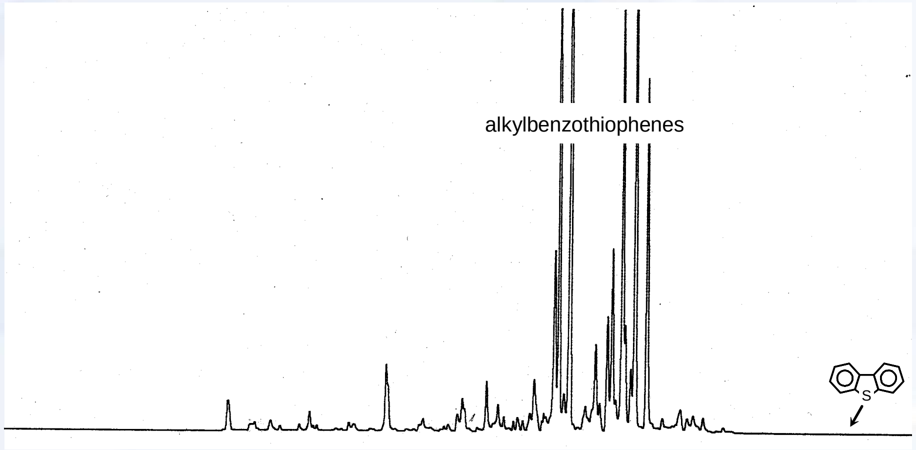
Milestone	TRL	Measure of Success	TRL Date
Breadboard	4	Fundamental operation validated	
Prototype	5/6	Operation at selected environments	

Sulfur Mgmt for Logistical Fuels

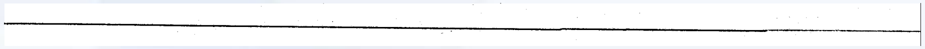
Reduction of logistical fuel sulfur content required for use in fuel processor and fuel cell

- TFCG utilizes re-generable sulfur absorbent
- Sulfur reduction of JP-8 from 1650 ppm_w to 15 ppm_w and of diesel from 330 ppm_w to 30 ppm_w has been demonstrated
- Over 1300 operational hours comprising over 40 operation-regeneration cycles have been demonstrated
- Logistical fuel yields of > 99% have been demonstrated

1650 ppm_w S Jet-A

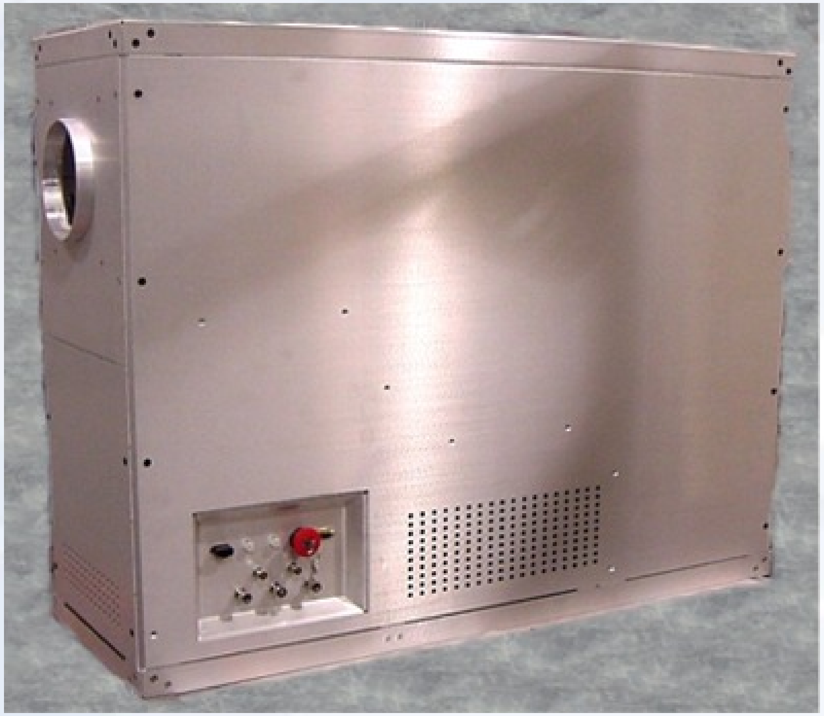


15 ppm_w S desulfurized Jet-A



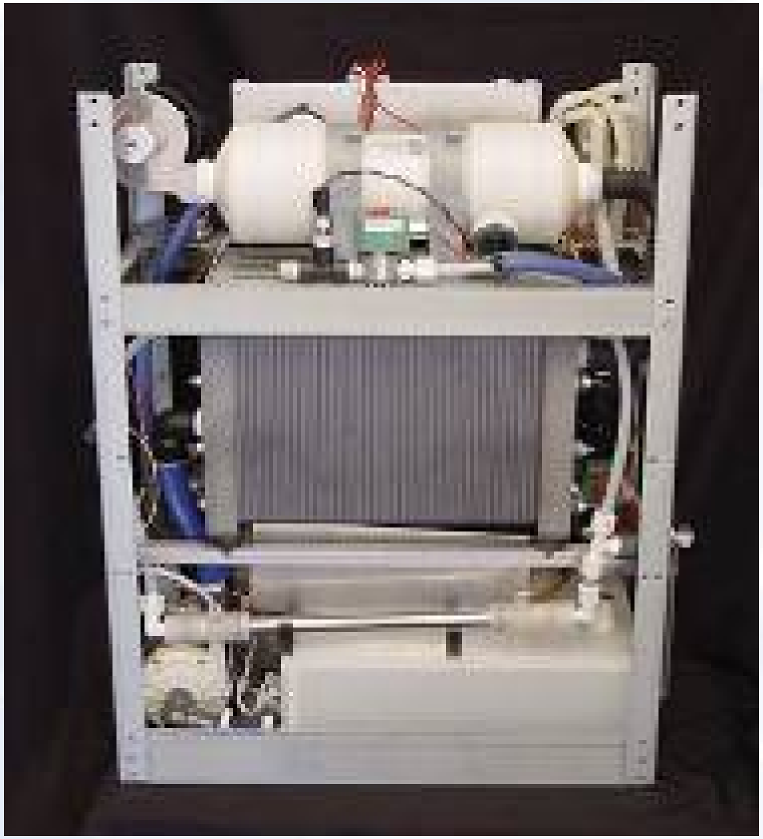
Converting Logistical Fuel into a Hydrogen Rich Stream

- TFCG fuel processor has produced hydrogen of suitable quality (> 99.9 % H_2) and quantity (> 50 sLm H_2) to operate as a 3 kW_e generator
- Fuel processor thermal efficiency of > 70% demonstrated
- Over 800 operational hours comprising over 70 start up – shut down cycles have been demonstrated
- Fuel conversions of > 99% have been demonstrated

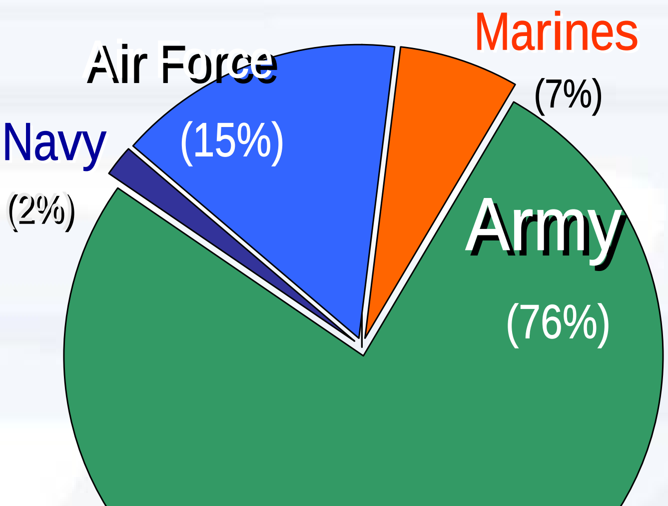


Converting Hydrogen into Electricity

- TFCG PEM fuel cell has demonstrated rapid start (< 1 min)
- Demonstrated fuel cell module efficiency of > 50%
- Low operating temperature yields minimal thermal signature
- Low vibration level compared with ICE
- Minimal maintenance level (oil-less system)



What is the Military Market?



Size	Army # Req'd*	% Army Total	Qty Fielded	% Size Fielded
2kW	9,576	14%	8,155	85%
3kW	19,122	29%	8,761	46%
5kW	14,779	22%	8,625	58%
10kW	12,001	18%	8,692	72%
15kW	4,370	7%	2,948	67%
30kW	3,085	5%	2,345	76%
60kW	2,950	4%	1,684	57%
100/200/DPGDS	568	1%	25	4%
	66,451		41,235	61%

* BOIP05

2kW thru 920kW Generator Sets

(Does Not Include APUs)

Requirements		Fielded MIL-STD	Fielded TQG
Army	66,451	25,216	41,235
Navy	1,540	721	819
Air Force	13,340	3,787	9,553
Marines*	6,423	305	6,118
Total	87,754	30,029	57,725

* USMC Requirements Under Review

Data Thru Apr 06

USMC

Most Recent Generator Set Procurement

2kW MTG 229

For delivery Nov 2006 – Feb 2007

Ongoing Generator Set Deliveries through 1QFY08

10kW TQG 621

30kW TQG 100

60kW TQG 684

100kW TQG 253

200kW TQG 79

Total 1,966

2kW – 200kW Generator Sets

MIL-STD = Military Standard
First Generation Gasoline and Diesel Engine Generator Sets

TQG = Tactical Quiet Generator
Second Generation, Modernized, Diesel Engine Generator Sets

MTG – Military Tactical Generator

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Army Applications (continued)

- Squad Charger


- Field Battery Charger


- Reduction in total Batteries

- Robotics Power, IED Detection


Fuel Cell Systems for Defense Applications

- 3 kW_e Tactical Fuel Cell Generator

- ***250 watt Fuel Cell Battery Charger (and small Tactical Generator)***

Relevant to 2 of 5 Soldier Modes of Maneuver: dismounted & air assault

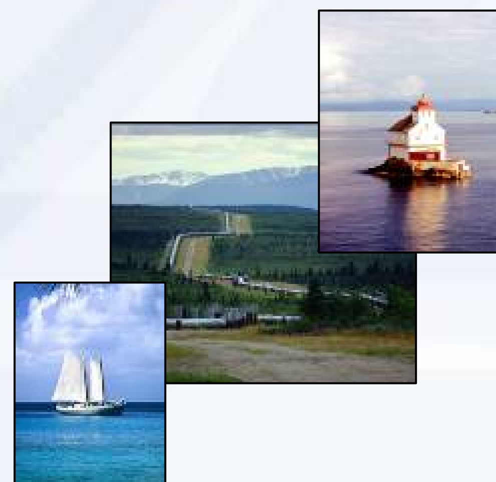
Fuel Cell Battery Charger System

Need – military battery charging and portable power for tactical theaters and training facilities

Operational Gap – Warfighters carry many primary batteries to accomplish 1 to 3 day missions. Fuel Cell Battery Charger supports the use of advanced rechargeable batteries, reducing total battery load

Technology Development Milestones to Date

Milestone	TRL	Measure of Success	TRL Date
Breadboard	4	Fundamental operation validated	11/04
Prototype	5	Operation at selected environments	11/06
Commercial	6	CE certification earned	2007



Fuel Cell Battery Charger System

Specification

- 250 Watt, 12/24 VDC
- 14 x 6.5 x 20”
- Methanol / water fuel
- 500 ml/hour fuel consumption
- 42 cfm air vent.
- IP20 (NEMA 1)
- CE Certified

Features

- Recharges military batteries and performs as a tactical generator
- On-board reformer converts MeOH/H_2O to H_2
- Silent Watch – capable
- Logistic simplicity – only fuel
- Will start in 5 minutes (militarized)
- Will meet TQG environmental spec.

Tactical Generator Application

Fuel Cell Battery Charger System

Current Military Test & Evaluation

- Army Communications-Electronics RD&E Center
- Naval Surface Warfare Center Carderock Division

Advanced Development

- Lighter, smaller
- Increase energy density
- MIL-STD compliance (similar to TQG requirements)
- Faster startup time
- Luggable configuration with rapid field assembly
- Durable lifetime

Military Battery Charger Application

FCBCS Reduces Lugged System Weight

Weight Advantage – 72 hour mission, LW Platoon / I.S.

Batteries Only

Quantity Batteries	Battery Weight
738 Li 145	1,660 lbs.

- 1,660 – 420 = 1,240 lbs. using 1 FCBCS (**75% weight reduction**)
- 1,660 – 444 = 1,216 lbs. using 2 FCBCS (**73% weight reduction**)

FCBCS

Quantity Batteries	Battery Weight	# FCBCS / Platoon	FCBCS Weight	Fuel Weight	Total Weight
164 Li 145	369 lbs.	1	24 lbs.	27 lbs.	420 lbs.

Weight Advantage – 96 hour mission

- **2,214 – 429 = 1,785 lbs. using 1 FCBCS (81% reduction)**
- **2,214 – 453 = 1,761 lbs. using 2 FCBCS (80% reduction)**

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Acquisition Cost Advantage

Cost Advantage – 72 hour mission, LW Platoon / I.S.

Batteries Only

Quantity Batteries	Battery Cost
738 Li 145	$221,400

FCBCS

Quantity Batteries	# FCBCS / Platoon	Total Cost
164 Li 145	1	$60,600

- $221,400 – 60,600 = $160,800 using 1 FCBCS (**73% cost reduction**)
- $221,400 – 72,000 = $149,400 using 2 FCBCS (**67% cost reduction**)

Cost Advantage – 96 hour mission

- **$295,200 – 60,660 = $234,540 using 1 FCBCS (79 % red.)**
- **$296,200 – 72,060 = $224,140 using 2 FCBCS (76 % red.)**

System Interface (Commercial Config.)

Air Intake Guards

On/Off

Fault Indicator

RS232 Interface

DC Input/Output 12/24V

Fuel In & Emergency Disconnect

Remote Interface

Fuel Return

Powered by IdaTech®

Questions?

www.idatech.com
info@idatech.com
63065 NE 18th Street
Bend, Oregon 97701

Millennium Cell

The Hydrogen Battery Technology Company

Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications

Joint Services Expo, San Diego, CA
Apr 24-26, 2007

Shailesh A. Shah
Marketing Director, Military

Millennium Cell Inc.
One Industrial Way West
Eatontown, NJ 07724
shah@*millenniumcell.com*
732-542-4000

Who is Millennium Cell?

Millennium Cell
The Hydrogen Battery Technology Company

- The Hydrogen Battery Technology Company
  - Formed in 1998 and went public in 2000
  - Ticker symbol “MCEL”, NASDAQ market
- Hydrogen storage and passive PEM systems
  - **Chemical hydride expertise**
  - **Recently acquired Gecko Energy Technologies, a passive PEM fuel cell company**
  - Over 30 patents granted and 74 pending
- Focused on portable applications under 500 watts

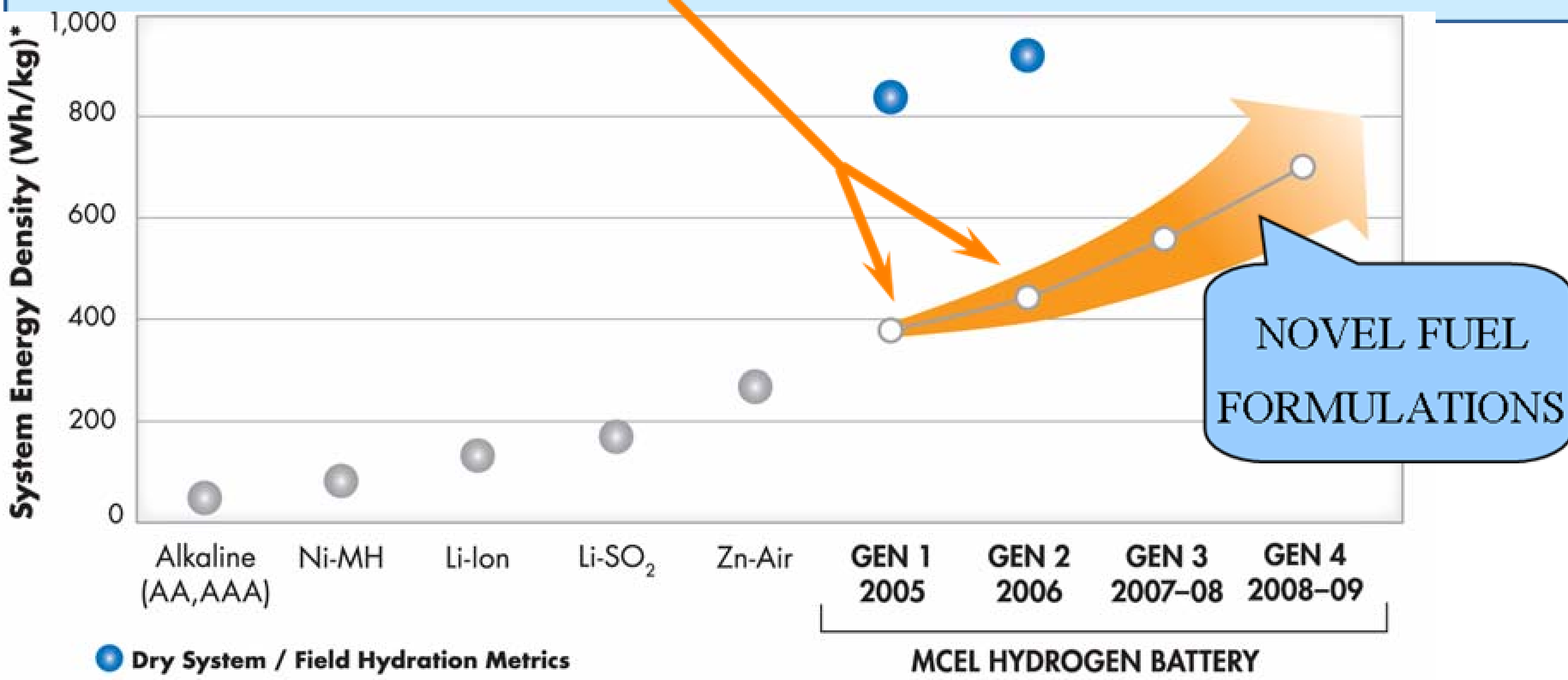
Strategic Relationships

- Collaboration to accelerate the commercialization of portable fuel cells
- Portable System Development
  - PEM fuel cell developers and licensees
  - Military development programs
  - Working with non-profit groups

Hydrogen Battery Technology
Hydrogen on Demand® Reaction

Millennium Cell
The Hydrogen Battery

$$\underbrace{NaBH_4\,(aq) + 4\,H_2O}_{\text{An energy-dense chemical hydride fuel}} \underbrace{\xrightarrow{cat}}_{\text{Rapid } H_2 \text{ production}} \underbrace{4\,H_2}_{\text{High purity hydrogen}} + \underbrace{NaB(OH)_4\,(aq)}_{\text{Borate can be recycled or disposed}} + \underbrace{\text{heat}}_{\text{No heat input}}$$



*Based on a 30W, 72 hour military mission

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Multiple Platforms for Military Applications

Millennium Cell
The Hydrogen Battery Technology Company

- **Sub 20 Watt Passive Platform**
  - Long run time wireless sensors
  - Rugged IT
- **20 – 100 Watt Platform**
  - Soldier Power
  - Military Radios
- **100 – 300 Watt Platform**
  - UAV, UGV
  - Battery Charging
  - Medical Evacuation
- **500 Watt Platform**
  - Critical Emergency Power
  - Remote Power

- **High Energy Density Fuel**
  - Less Weight
  - Less Volume
- **Safe**
- **Indefinite Shelf Life**
- **Fuel Gauge**
- **Hot Swappable Cartridge**
- **Silent Power**
- **Low Thermal Signature**

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Product Development

Passive platform for < 20 W applications

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- Initial demonstration system
- Uses Gecko passive PEM fuel cell
  - High power density → fits in device
  - High efficiency → lower waste heat
  - Simple architecture with minimal BOP
  - Low cost → < $5 per watt
  - Thin, flat form factor → no extra volume
- Passive HOD™ system
- Target Applications:
  - wireless sensors,
  - handset chargers,
  - wearable power,
  - perimeter security

Night Vision Camera

First demonstrated in Sep 2006

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Product Development

Protonex + Millennium Cell

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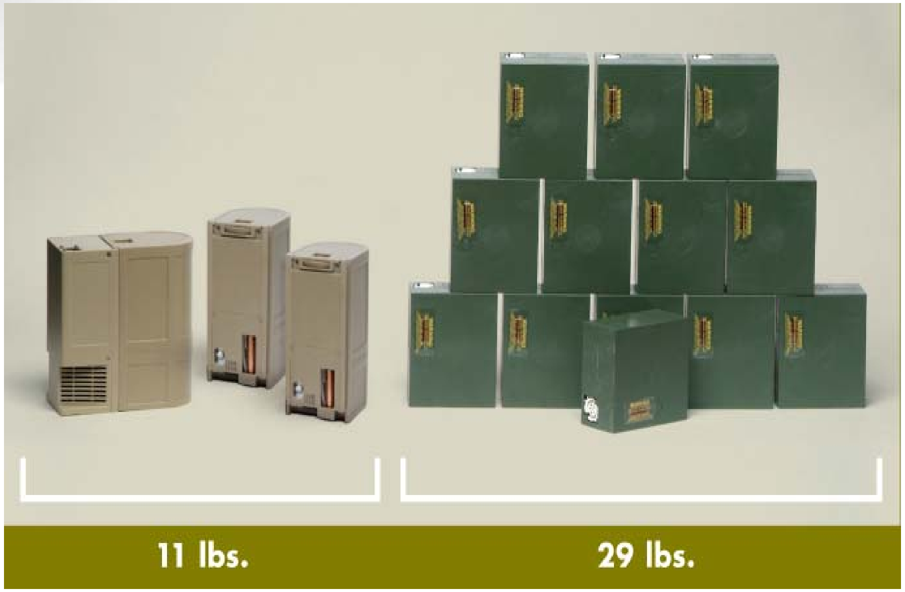
30W Soldier Power System



- 30 W x 72 hour mission
- 66 % Lighter than BA 5590
- 20 % Cheaper

150W UAV Power System

- Enables 4X – 6X Flight times

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Product Development
Jadoo + Millennium Cell

The Hydrogen Battery Technology Company

SOCOM PSC-5D Radio

- 55 W nominal power
- Fits in 2 x BA 5590 battery box

N-StorNB

eXtended Run Time

- 100 W Auxiliary Power
- 2200 Wh Energy
- 110 V, 12 V interface

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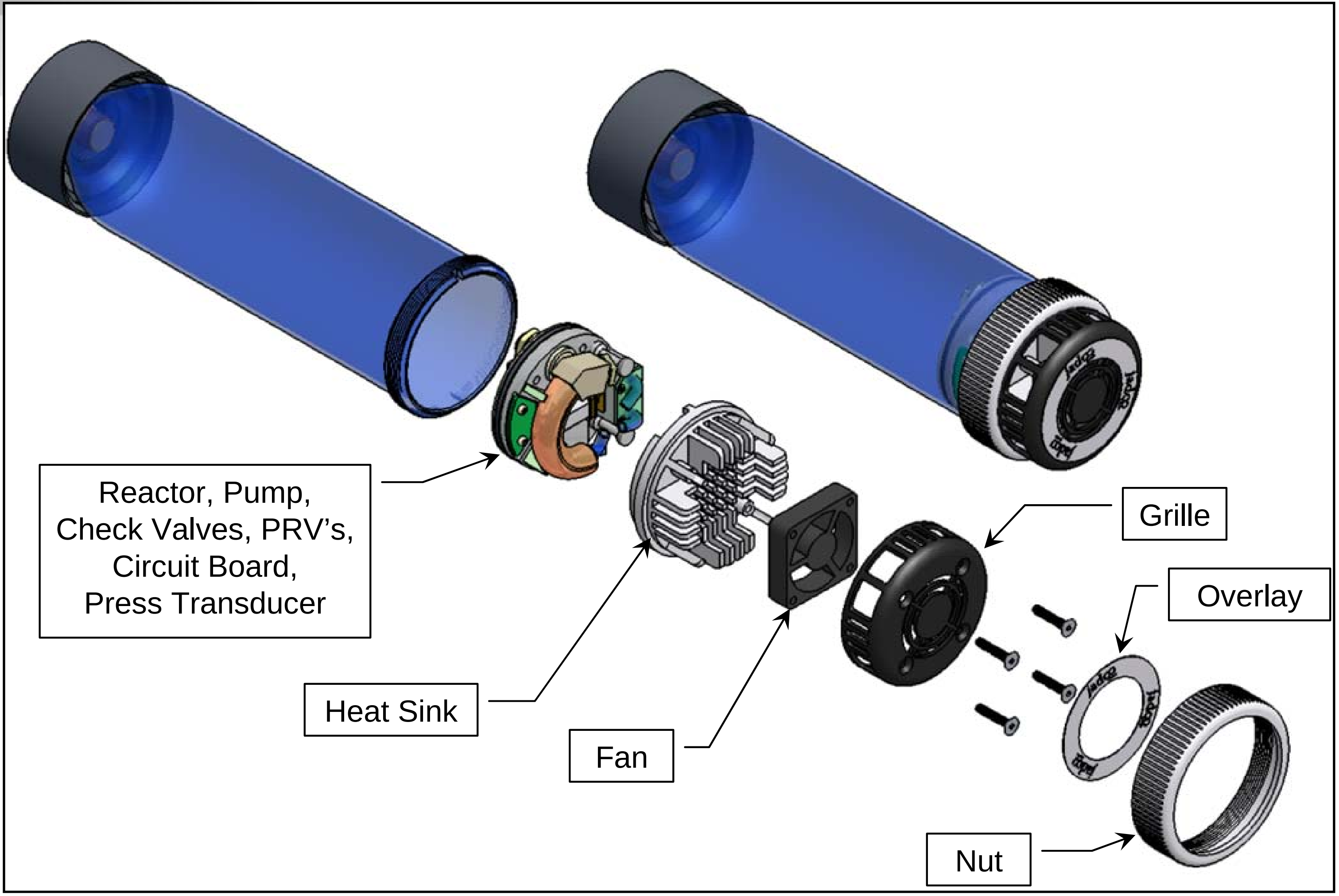
Cartridge Detail View
N-StorNB (NB: Sodium Borohydride)



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Value Proposition

Special Operations Radio

Millennium Cell

The Hydrogen Battery Technology Company

Based on 11 day mission	Jadoo & MCEL Fuel Cell System	BA-5590 Battery
Configuration for mission	1 Fuel Cell 7 x 500 W-hr Fuel Cartridges	35 Battery Packs
Weight of System	11 kg (24 lbs)	36 kg (79 lbs)

Status: First prototype demonstrated Sept. 2006
Delivery to SOCOM in Q2-07

Competitive: Advantage: Field hydration, non-flammable fuel
66% lighter than BA5590

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Product Development

Cartridge manufacturing

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- Development programs to establish manufacturing technologies for cartridge components
  - Catalyst material / reactors
  - Fuel / byproduct assemblies
  - Cartridge shell
  - BOP components (e.g., pumps, valves)

- Materials and processes scaleable to higher volume production
- Recently established in-house manufacturing capacity to support initial cartridge sampling
  - ~250 cartridges for evaluation in South Carolina in 2007-8

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Summary

Millennium Cell
The Hydrogen Battery Technology Company

- Significant Sodium borohydride ($NaBH_4$) expertise
- Novel Fuel Formulations offer higher energy density
- Portable systems being evaluated by military partners → Field Trials this year
- Technology development → product development / manufacturing
- Developing 3 – 5 Watt passive fuel cell systems

Thank you!

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